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CONCEPTS FOR DESIGN OF LIGHTWEIGHT TRACK FOR THE U.S. MARINE LANDING VEHICLE ASSAULT (LVA)

ALUMINUM COMPANY OF AMERICA

PREPARED FOR
DAVID W. TAYLOR NAVAL SHIP
RESEARCH AND DEVELOPMENT CENTER

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FINAL REPORT

PREPARED FOR
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CONTRACT N00167-76-C-0094
20 FEBRUARY 1976

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ABSTRACT

Future military vehicles require significant attention to vehicle weight if the desired advantages of battlefield mobility are to be achieved. Advancements in power-train and material technology will contribute to the design improvements necessary for these vehicles. Use of high strength to weight ratio materials is being stressed, wherever technically advisable and economically cost effective.

As part of the design considerations for a future U. S. Marine Corps amphibious personnel carrier type vehicle, Landing Vehicle Assault (LVA), the feasibility of using a lightweight aluminum track has been examined. Four concepts for a LVA track that would achieve significant weight savings compared to existing steel tracks are examined. Two concepts are suggested for further evaluation, prototyping, and vehicle testing. Preliminary weight and production price estimates are made.

FOREWARD

This effort is in support of the Landing Vehicle Assault (LVA) Development Program under the management of the Naval Sea Systems Command, Code 03221. The work was done under contract to the David Taylor Naval Ship Research and Development Center, with technical monitoring by DTNSRDC, Code 112.

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(Drawings in pocket, back cover)

SECTION I

INTRODUCTION TO LVA VEHICLE AND TRACK REQUIREMENTS

A future mix of U. S. military combat vehicles is now being proposed for limited warfare scenarios that require high battlefield mobility. These vehicles must also provide increased armor protection and battlefield firepower effectiveness to combat the increased threats of future enemy hardware. High vehicle mobility will be achieved by advancements in power-train technology and use of high strength, low weight materials where they are most cost-effective. Throughout these designs there is a simply stated, but not so simply achieved, necessity to minimize gross vehicle weight. Proper choice and practical utilization of lightweight materials is essential if the advantages of battlefield mobility are to be achieved.

The U. S. Marine Corps has identified the operational need for an amphibious vehicle that will meet the surface mobility and combat support requirements of the post-1980 time frame. Development of this vehicle, the Landing Vehicle Assault (LVA), is to include examination of designs that will be capable of transporting and supporting assault forces during "over the horizon" amphibious landings and subsequent operations ashore.[1]

As part of the LVA design considerations, the feasibility of using an aluminum track has herein been examined. Aluminum tracks have been proposed, tested, and used on several production vehicles since the late 1950's. Recent programs have demonstrated the advantage of lighter weight aluminum tracks for heavy battle-tank type vehicles.[2] The effort under this David Taylor Naval Ship Research and Development Center contract has been to examine concepts for a Landing Vehicle Assault track that will achieve significant weight savings compared to existing steel tracks used on this type of tracked vehicle. The track and suspension system of the present vehicle, the LVTP-7, was used as the basis for these design concepts. The goal of this study was to suggest the design(s) for the lightest weight aluminum track that might meet the track requirements of a vehicle in the weight and performance classification of the LVTP-7; this design(s) concept could then be further developed and evaluated for the LVA[3]. As such the following general guidelines were followed:

1. 21" track width
2. 50,000 lb. class vehicle
3. Track performance equal to LVTP-7 track
4. Replaceable road surface pads
5. Interchangeability of component parts with existing tracks where possible (without increasing weight or degrading performance)

The study focused on those areas that have historically been identified as possible deficiencies in the operation of a single-pin aluminum track. Special attention was given to field and/or depot replacement of critical wear areas, particularly the sprocket engagement and centerguide areas of the track shoe body. This replacement of selected, preidentified, life-limited track components would extend the operational use of the basic track shoe body to its maximum life (determined by metal fatigue limit or failure/wear of rubber components).

Possible follow-on programs utilizing experimental stress analysis and laboratory testing of actual prototype hardware to more fully examine and refine the most promising design(s) are identified in Section V.

SECTION II

BASIS FOR TRACK DESIGN CONCEPTS

Historically there have been several concerns with aluminum track systems:

1. Abrasion resistance of the drive areas

2. Strength of the basic shoe body under track tension, bending, and torsional loads

3. Strength and wear resistance of the centerguide area

Throughout this analysis, special attention was placed on resolving the strength and abrasion resistance concerns of the drive and centerguide locations.

Several previous aluminum track programs have examined and demonstrated the advantages of a double-pin (versus single-pin) design in eliminating items 1 and 3 above by using separate hardened steel components in critical wear areas. Examples of double-pin designs are the T-142 track used on the M60 and M48 battle tanks (shown in its aluminum version in Figures 1 and 2) and the aluminum T-144 Hawk Missile Loader Vehicle track (shown in cross section in Figure 3). By comparison, the shoe body of a single-pin track (the T-130) is shown in Figure 4. The double-pin design is penalized in weight by the addition of the second pin and separate connecting hardware, but it uses a simpler block design than a single-pin track. The additional pin does result in lower rubber bushing loads, a definite advantage for increasing the lifetime of a heavily loaded truck.

The challenge herein was to examine "lightweight" design concepts that would meet the LVA requirements. Therefore, both double- and single-pin tracks were examined. Four track concepts were studied, one of which is a double-pin design similar to the M109 Howitzer's steel T-136 track; the remaining three single-pin tracks are based on the LVTP-7 track. It was felt the single-pin design offered a weight advantage but created problems in prevention of sprocket and centerguide area wear. Single-pin aluminum tracks are not proven in service, as are several double-pin tracks, but it was felt a single-pin design should be thoroughly reviewed for the LVA because of its advantages for weight reduction.

Attention was first placed on the centerguide, with the basic decision that the centerguide would be integral to the block to achieve maximum shoe area at minimum weight. This is opposed to a separate centerguide bolted to the pin, as in the case of the T-142. This type of design (used in the T-136, T-144, and the LVTP-7 tracks) would require protecting the aluminum "horn" with the steel "cap." Several concepts have been examined and proven successful over the years. Pictured in Figure 3 is a cross section of the aluminum Hawk Missile Loader Vehicle T-144 track, its centerguide is integral to the track body and its steel protection is bonded to the aluminum by rubber. This concept has worked in production, and the bond has proven to be durable in vehicle operation. This rubber bonded cap concept, if restricted to the over-all dimensions of the LVTP-7 track guide, would not provide sufficient lateral strength in the guide and would possibly even be too thin to forge economically in a typical forging operation. This type of protective cap could be used successfully on the LVA if the roadwheel guide area were widened to permit a thicker guide horn, particularly at the horn base. A disadvantage of the rubber bonded steel cap is that it cannot be replaced without rerubberizing the entire track body. It would not be field repairable and therefore is not felt to be cost effective in extending the over-all track life.

Throughout this effort, concepts to fully utilize components that could be replaced not only for routine maintenance but also for emergency field repair were stressed. Therefore, a centerguide concept was envisioned in which the centerguide would be made of a steel casting or forging and held in place by bolts through the aluminum block. This concept could be made to the dimensions of the existing LVTP-7 and would allow the desired field replacement of worn components. In each of the four basic designs evaluated under this contract, the replaceable centerguide concept is suggested. In all designs, the centerguide location has been toward the forward area of the body so that the track centerguide comes into contact with the roadwheel prior to application of the full weight of the wheel on the track, thus providing a better alignment of the track system and less wear. Worst-case centerguide side loads have been computed and are included in Appendix A. Some consideration might be given to using the same bolt assembly for retaining both the track pad and the centerguide as a possible step to further reduce weight and the number of hardware parts.

The other track area requiring abrasion resistance, namely the sprocket engagement location, was likewise considered for a replaceable, easy maintenance component. In the case of the double-pin design, the drive system utilizes "end connectors" of hardened steel that could be replaced as required. In the case of a single-pin design such as used on the LVTP-7, the replacement of sprocket wear areas requires replacement of the entire shoe. In fact, the U. S. Marine Corps has said that the main reason for replacement of the LTVP-7 track is wear of the track body sprocket drive area. Therefore, to counter the known problems with an aluminum forging in this application, and also to provide the desired ease of maintenance, a separate body insert or end drive system was included in each of the four designs considered. (Note that the insert concept (Number 4) would require minimum alteration to the existing LVTP-7 suspension.) By careful consideration, the anticipated problems with wear have been overcome in these designs through utilization of replaceable steel components.

The basic track block concept is a redesign of the existing steel LVTP-7 track (single pin) or the T-136 track (double pin). It is assumed that the LVA as it is finally designed will be of the same weight class and have similar land performance requirements as the existing LTVP-7. Attempts were not made under this contract to describe a general purpose track but rather to refine the existing track and drive systems so that a lighter weight track could be used successfully. A basic consideration in the design philosophy was also that the vehicle never will be operated without the road surface pads, and that the replaceable feature of the pad is for simple replacement of worn out pads (as opposed to providing a combat configuration; i.e., without pads). Therefore, all designs have included a replaceable road surface pad that will be in place at all times. Track loads are also assumed to be essentially the same as that of the existing tracks since the vehicle weight and performance requirements have not been appreciably changed. In all cases, hardware components such as the pins, pads, bushings, and nuts and bolts have been designed, wherever possible, to be the same as those used in existing, fielded tracks. In cases where it was felt additional strength or dimensional changes were required, new hardware components have been suggested, although detailed specific designs are beyond the scope of this effort.

SECTION III
TRACK CONCEPTS

Concept 1 - Single-pin with end drive (Drawing No. B-100504-AE). This design was the first considered, and was derived from the LVTP-7 track by modifying the section properties where necessary. The section property analysis of this redesign is contained in Appendix B. Basically, this design utilizes a replaceable steel centerguide in conjunction with sprocket engagement on a steel sleeve over the end of the shoe body. In this concept the steel sleeve drive area is not truly replaceable although the shoe could be refurbished in a maintenance depot. The steel sleeve could fit either over the forging itself or ride on a separate bushing assembly. As pictured, the sleeve fits directly on the aluminum shoe, although this could result in abrasion and wear of the aluminum forging if the sleeve began to rotate on the forging. If this system were to be field replaceable, it would be necessary to provide a bushing for the drive sleeve to fit directly on the pin. This bushing could be made free to rotate, thereby distributing the wear over the sleeve surface and reducing power loss to friction between the track and sprocket. With minor alterations, the shoe pad and bolt assembly would be the same as the existing track. The pin and bushings likewise could be the existing parts. It was felt in this analysis that because of higher loads at the ends of the block due to the drive mechanism location, this portion of the track body should be strengthened and possibly a 1-inch (diagonal distance) octagonal pin used instead of the current 13/16-inch octagonal pin. The estimated weight for this design in a complete assembly is 22.8 pounds per pitch or approximately 45.6 pounds per running foot of track. The 6-inch pitch and 21-inch width have been retained from the existing LVTP-7 track. This concept would obviously require a different sprocket hub than the existing vehicle since the sprocket must engage over the ends of the track pins and not in the block itsef; the same sprocket design might be used, however.

<u>Concept 2 - Single pin with end drive, modified (Drawing No. B-100508-AE)</u>. This concept utilizes the basic type of end drive as proposed in Concept 1 with modifications for additional strength through the shoe body, particularly in the drive location. Also included is a heavier pin to take the increased loads at the drive location. The sprocket engagement area in this case is a separate steel component riding directly on a pin bushing; and the drive assembly is held in place by the pin nut and an auxiliary bolt into the shoe body. Load conditions were examined for a general end drive type design, particulary through Section Y-Y, and additional strength

was suggested to maintain a satisfactory design margin. These analyses are shown in Appendix C. The centerguide used in this concept is the same as that proposed in Concept 1. An alternate guide proposal is shown in View 2 that uses a single 1/2-inch bolt for attachment of the centerguide (as opposed to using two 1/4-inch bolts). This change was for ease of handling during assembly and maintenance of the track, and to strengthen the assembly. The end drive component for the drive sprocket engagement is essentially the same physical size as the existing engagement area on the LVTP-7 so that, other than sprocket location, the same sprocket could be used (as also indicated for Concept 1). Use of the 1-inch pin causes a weight increase of approximately 1-1/2 pounds over the existing 13/16-inch pin but it is felt that it will be required because of the increased load on the pin at the drive location. Additional analysis may reduce this weight penalty by demonstrating that a hollow or smaller pin is adequate. Concept 2 as shown uses a three-lobe track body as opposed to the five-lobe body of the LTVP-7; the change is to permit strengthening the body at the end drive location. The road surface pad, as in the preceding concept, is replaceable and bolted through the center of the track block. The pad configuration has not been specifically defined but is expected to be similar to the LVTP-7. In both of these drive systems, the existing type of octagonal pin and separate rubber bushings is retained.

Concept 2 is essentially a refinement of Concept 1 improving the areas identified as having possible weaknesses. This track would require slight suspension redesign from the LVTP-7 (drive sprockets), and would not use existing pin or bushing hardware. The estimated weight for Concept 2 is 25.6 pounds per shoe, or 51.2 pounds per foot.

Concept 3 - Double-pin with end drive (Drawing No. B-100513-AE). This double-pin track concept is basically a revision of the 15-inch T-136 track used on the M108/M109 self-propelled howitzer. The track body contains an integral centerguide. The track width would be extended to the total 21-inches suggested for the LVA and the pitch opened to 6-inches. As opposed to T-142 double-pin track (Figures 1 and 2), this concept uses a single block with a centerguide directly attached to the track block itself. The centerguide arrangement is basically that suggested on the previously described single-pin designs. The track pad, like the other designs, is replaceable and held in place by a nut and bolt through the track body. As this is a more extensive redesign of the T-136, the hardware (i.e. the pads and pins) would not be those used in production for the current track. The double-pin design does have an advantage in being driven off the steel end connectors and it has been proven in actual field use of aluminum tracks. Also, the track body geometry is less susceptible to stress concentrators that could cause failures. Thus, this track is a lower risk development than the single-pin track although it does weigh more due to its double pin and more massive block arrangement. The centerguide concept here shown in Section AA and BB could use a riveted steel cap as an alternate method of providing protection to the aluminum horn. The centerguide would then not be replaceable except by refurbishment in a maintenance depot, although a weight reduction and simplification of track parts would result. This concept is estimated to weigh 32.8 pounds per shoe or 65.6 pounds per foot.

Concept 4 - Single pin with track body drive (Drawing No. B-100514-AE). This design physically is the closest to the existing LVTP-7 track, and retains the basic five-lobe design with chevron-type grouser and replaceable rubber pads. The same octagonal pin and bushing arrangement is also retained. The block design and section properties are basically the same as those proposed in Concept 1. The centerguide would be the bonded or riveted "cap" or the bolted design discussed previously. The significance difference in this concept is the use of a replaceable steel insert in the track block drive area. These steel inserts are held in place by a retaining strap bolted into the body. As opposed to the previous concepts, and more like a conventional single-pin track, the area of sprocket engagement is in the track block. To prevent possible entrapment of foreign matter that would create sprocket/track block interference and misguiding, the block is open through the engagement area. Because of the drive location, the grouser sectional area may be limited relative to that suggested in Concepts 1-3. This could restrict enlarging the rubber pad (to reduce the vehicle ground pressure); larger pads would be possible in the other concepts. However, the track would be directly replaceable on the LTVP-7 with little, if any, change to the existing vehicle. The steel drive inserts are themselves a weight penalty of approximately two to three pounds per block. Weight reduction in this area might be achieved by hollowing a portion of the steel inserts, and providing a single bolt attachment for the retaining strap. The drive area is slightly smaller than that of the existing track but is large enough to accommodate the sprocket as currently designed. As shown, this design would weigh 25.7 pounds per shoe or 51.4 pounds per foot of track.

SECTION IV

ALUMINUM ALLOY DOCUMENTATION; WEIGHT AND PRODUCTION COST ESTIMATES

The four designs considered are based on use of the mechanical properties of 2014-T61 die forgings. The alloy, as characterized in Figure 5, has seen wide use in aircraft and ordnance parts where high tensile and yield strengths are required. It is a good, economical forging alloy and has good machinability with acceptable resistance to corrosion for this application. The T-144 and T-142 tracks have been made in 2014 with resulting excellent field performance. Figures 5 and 6 summarize the characteristics and typical mechanical properties of die forgings in a number of aluminum alloys. Higher strength alloys, such as 7075 are available and might provide a higher margin in the design and/or allow weight reduction in the track body, but at a higher cost. Additional analysis is required on actual hardware (Section V) to define specific stress levels before making alloy or design refinements.

A weight summary of the four proposed concepts is included in Figure 7. This summary shows Concept 1, the single-pin with end drive is the lightest of the four concepts at 45.6 pounds per foot. The double-pin track, Concept 3, is the heaviest at 65.6 pounds per foot. Intermediate are the modified single pin, Concept 2, at 51.2 pounds per foot, and the track body drive single pin, Concept 4, at 51.4 pounds per foot.

Recommendations included in Section V suggests Concepts 2 and 4 be pursued for hardware analysis and prototype testing. Production cost estimates have been made for these concepts, and are given in Figure 8. It should be noted that these estimates are made without complete details of the actual finished designs, and are in 1976 dollars.

SECTION V
RECOMMENDATIONS

Three of the four concepts evaluated involve several distinctively different approaches to a lighter weight track for a future vehicle. (Note that Concept 2 is an evolution of Concept 1 that incorporates modifications aimed at eliminating weaknesses). Because of the emphasis on lightweight, and the weight classification of the vehicle, a single-pin design offers over-all advantages and possible commonality of hardware with other vehicle tracks. The primary emphasis herein has been to reduce weight while maintaining the same performance level designed into present tracks. In addition, considerable attention has been placed on replacement of wear areas (the centerguide and track drive locations) to achieve maximum track life, and therefore cost effectiveness of the indivdual track components. The double-pin track repres[illegible] less of a technical risk in that this type of track has been designed, tested, and produced for vehicle use and has per[illegible] satisfactorily. However the heavier weight is not desirable. The [illegible]le-pin design is therefore not recommended for further evaluation. The single-pin designs described in Concepts 2 and 4 offer the best combination of weight savings, chance for technical success, potential cost effectiveness, and commonality with existing hardware that is desired for the LVA and other future vehicles.

Additional stress analysis of the basic track body is required before either of these designs be carried further. It is recommended that laboratory analysis of hardware (i.e. castings) be carried out to refine these designs and that the resultant final concept be made into prototype track for further qualification testing. This would include verification laboratory tests of actual production produced die forgings, and to be followed by assembly into track sections for vehicle testing.

SECTION VI

REFERENCES

1. Tentative Specific Operational Requirement, (MOB-1.05T) Landing Vehicle Assault (LVA).

2. "The Development and Use of Aluminum Track for Military Vehicles," W. J. Lane, September 1975.

3. "Proposal for a Design Study of Lightweight Track for the U. S. Marine Corps Landing Vehicle Assault (LVA)." May 23, 1975.

4. "Mechanical Engineering Design," J. E. Shigley, McGraw Hill, 1963, pp 158, 183.

APPENDIX A

CENTERGUIDE LOAD ANALYSIS

Assumptions:

1. Maximum vehicle roll angle (side slope) is 40^0
2. There are six road wheels on each side
3. The equivalent of at least one centerguide is in contact with each wheel (at any one time)
4. The worst possible case is for six centerguides to hold the maximum vehicle side load (ignores friction between roadwheel and track body)
5. Maximum vehicle weight is 50,000 pounds
6. The load on each centerguide is concentrated at a point 1-1/2 inches from the guide tip (center of observed wear pattern on LVTP-7 track)

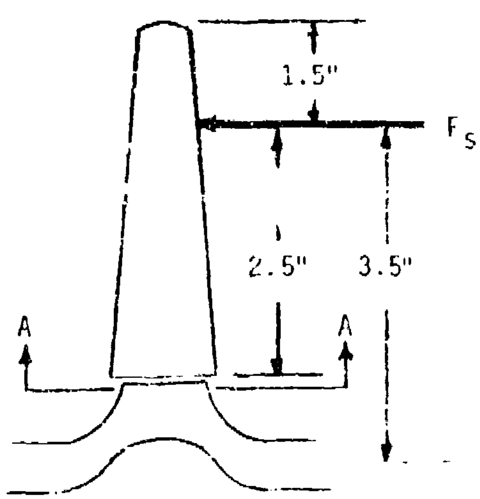
Then:

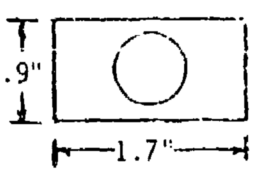
The side load on each guide is given by

$$F_S = \frac{(50{,}000 \text{ lb.})(\cos 50^0)}{6}$$

$$F_S = 5{,}356 \text{ lbs.}$$

The centerguide sections are shown:





Section A-A

$$M = (2.5)\ (5356) = 13{,}400 \text{ in.-lb.}$$

$$I_{xx} = \frac{BH^3}{12} - I \text{ bolt hole, } 9/16"$$

$$= \frac{(1.7)\ (.9)^3}{12} - .005 = .098 \text{ in.}^4$$

Appendix A - Continued

The maximum stress at the guide base is given by

$$\sigma_{max} = \frac{Mc}{I}$$

$M = 13,400$ in.-lb.
$c = .45$ in.
$I = .098$ in.^{4}

$$\sigma_{max} = 61,500 \text{ psi}$$

2014-T61 Typical Properties (from Figure 6)

Tensile strength	68,000 psi
Yield strength	56,000 psi

The above analysis depicts a suggested rare worst case situation, and does show yielding of the centerguiding area could occur. The centerguide area of the track block will, however, provide sufficient strength for generally encountered field conditions.

APPENDIX B

SECTION PROPERTIES

SUMMARY OF CONCEPTS 1 AND 2

CONCEPT 1 - Single pin with end drive; Drawing No. B-100504-AE

Section		Ixx	Iyy	Syy Left	Syy Right	Sxx Top	Sxx Bot.	Area	J_z
"X-X"	Steel	1.12	5.43	2.18	3.31	.989	.78	2.85	6.55
	Alum.	1.61	6.80	2.69	3.80	1.34	1.13	3.86	8.41
	% inc.	44%	25%	23%	15%	35%	45%	35%	
"Y-Y"	Steel	.33	.32	.55	.256	.400	.315	1.30	.65
	Alum.	.43	.45	.67	.38	.52	.41	1.71	.88
	% inc.	30%	41%	22%	48%	30%	30%	31%	
"Z-Z"	Steel	.156	.059	.11	.114	.207	.201	1.03	.215
	Alum.	.254	.083	.17	.145	.287	.330	1.26	.337
	% inc.	63%	40%	54%	27%	38%	64%	22%	
"O-O"	Steel	.012	124.38	11.85	11.85	.082	.015	2.62	124.4
	Alum.	.028	164.31	15.65	15.65	.182	.033	3.51	164.3
	% inc.	133%	32%	32%	32%	120%	120%	34%	
"B-B"	Steel	.010	16.43	3.46	3.46	.084	.012	2.18	16.44
	Alum.	.024	22.29	4.69	4.69	.159	.028	2.96	22.3
	% inc.	140%	35%	35%	35%	83	133%	36%	
"A-A"	Steel	1.87	160.07	20.29	20.29	1.61	1.34	6.68	161.9
	Alum.	2.84	271.51	34.21	34.21	2.33	2.02	10.67	274.3
	% inc.	52%	70%	69%	69%	45%	51%	60	

CONCEPT 2 - Single pin with end drive, modified; Drawing No. B-100508-AE

Section		Ixx	Iyy	Syy Left	Syy Right	Sxx Top	Sxx Bot.	Area	J_z
"A-A"	Steel	1.87	160.07	20.29	20.29	1.61	1.34	6.68	161.9
	Alum.	2.70	311.33	38.58	38.58	2.25	1.89	11.05	314.03
	% inc.	44%	94%	90%	90%	40%	41%	65%	
"X_2-X_2"	Steel	1.12	5.43	2.18	3.31	.989	.78	2.85	6.55
	Alum.	1.57	12.20	5.53	5.40	1.424	1.34	4.82	13.77
	% inc.	40%	125%	154%	63%	44%	72%	6[illegible]	
"Y-Y"	Steel	.33	.32	.55	.256	.400	.315	1.30	.65
	Alum.	.678	5.50	3.36	2.40	.653	.761	3.[illegible]6	6.178
	% inc.	105%	1616%	511%	837%	63%	141	151%	

SECTION PROPERTY DATA

DEFINITION OF RESULTS:

ARBITRARY AXIS

AREA-- AREA OF THE SECTION IN IN^2.
WT/FT- WEIGHT PER LINEAL FOOT IN POUNDS.
XBAR-- DISTANCE ALONG THE ARBITRARY X-AXIS FROM ITS ORIGIN TO THE NEUTRAL Y-AXIS IN INCHES.
YBAR-- DISTANCE ALONG THE ARBITRARY Y-AXIS FROM ITS ORIGIN TO THE NEUTRAL X-AXIS IN INCHES.
IXXA-- MOMENT OF INERTIA ABOUT THE ARBITRARY X-AXIS IN IN^4.
IYYA-- MOMENT OF INERTIA ABOUT THE ARBITRARY Y-AXIS IN IN^4.
IXYA-- PRODUCT OF INERTIA ABOUT THE ARBITRARY ORIGIN IN IN^4.

NEUTRAL AXES

FOUR VALUES OF SECTION MODULUS IN IN^3.
SXXTOP---IXXN/DISTANCE FROM AXIS XXN TO EXTREME FIBER AT TOP OF SECTION.
SXXBOT---IXXN/DISTANCE FROM AXIS XXN TO EXTREME FIBER AT BOTTOM OF SECTION.
SYYLEFT--IYYN/DISTANCE FROM AXIS YYN TO EXTREME FIBER AT LEFT SIDE OF SECTION.
SYYRIGHT-IYYN/DISTANCE FROM AXIS YYN TO EXTREME FIBER AT RIGHT SIDE OF SECTION.

IXXN-- MOMENT OF INERTIA ABOUT THE NEUTRAL X-AXIS (XXN) IN IN^4.
IYYN-- MOMENT OF INERTIA ABOUT THE NEUTRAL Y-AXIS (YYN) IN IN^4.
IXYN-- PRODUCT OF INERTIA ABOUT THE CENTROID IN IN^4.
IUUN-- A PRINCIPAL (MIN. OR MAX.) MOMENT OF INERTIA, AXIS UUN BEING THE ROTATED NEUTRAL X-AXIS (XXN) IN IN^4.
IVVN-- A PRINCIPAL (MIN. OR MAX.) MOMENT OF INERTIA, AXIS VVN BEING THE ROTATED NEUTRAL Y-AXIS (YYN) IN IN^4
BETA-- THE ANGLE BETWEEN THE U-AXIS (UUN) AND THE NEUTRAL X-AXIS (XXN), MEASURED FROM THE NEUTRAL X-AXIS (XXN) IN DEGREES(+ COUNTERCLOCKWISE)
RXXN-- RADIUS OF GYRATION WITH RESPECT TO THE NEUTRAL X-AXIS (XXN) IN INCHES.
RYYN-- RADIUS OF GYRATION WITH RESPECT TO THE NEUTRAL Y-AXIS (YYN) IN INCHES.
JZZN-- POLAR MOMENT OF INERTIA.

FOR FURTHER EXPLANATION OF THESE PROPERTIES SEE:

1. "FORMULAS FOR STRESS AND STRAIN" BY RAYMOND J. ROARK. PUB. McGRAW-HILL BOOK COMPANY, INCORPORATED.

2. "MECHANICS" BY J. L. MERIAM. PUB. JOHN WILEY & SONS, INCORPORATED.

3. "ALCOA STRUCTURAL HANDBOOK".

THE FOLLOWING SECTION PROPERTY DATA ARE
SUPPLIED BY ALCOA AS A SERVICE TO:

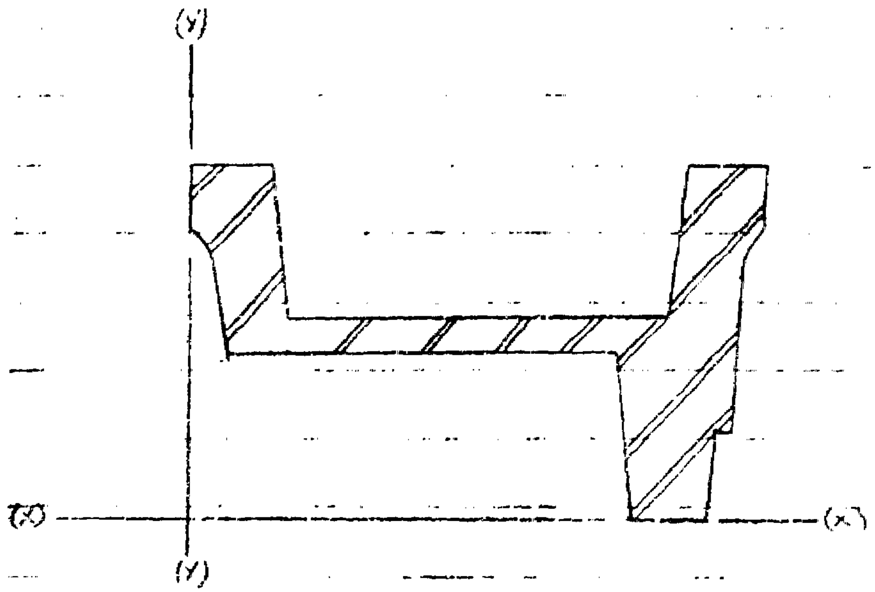
TRACK SHOE

SECT X-X STEEL

INPUT DATA:

I	X	Y	R	F
1	0.000	0.000	0.000	0.000
2	0.000	2.250	0.000	0.000
3	0.156	1.906	0.000	0.000
4	0.187	1.625	0.000	0.000
5	0.250	1.280	0.000	0.000
6	3.060	1.280	0.000	0.000
7	3.156	0.000	0.000	0.000
8	3.680	0.000	0.000	0.000
9	3.750	0.687	0.000	0.000
10	3.870	0.687	0.000	0.000
11	3.930	1.625	0.000	0.000
12	4.000	1.936	0.000	0.000
13	4.125	2.250	0.000	0.000
14	4.125	2.562	0.000	0.000
15	3.593	2.562	0.000	0.000
16	3.500	1.530	0.000	0.000
17	0.456	1.530	0.000	0.000
18	0.562	2.562	0.000	0.000
19	0.000	2.562	0.000	0.000
20	0.000	0.000	0.000	0.000

SECTION NOT SYMMETRICAL ABOUT X OR Y AXIS



THE RESULTS ARE:

969

ARBITRARY AXIS

AREA-- 2.84892
WT/FT- ~~3.39052~~
XBAR-- 2.48568
YBAR-- 1.43283
IXXA-- 6.96572
IYYA-- 23.03567
IXYA-- 9.23516

XMAX-- 4.125
XMIN-- 0.000
YMAX-- 2.562
YMIN-- 0.000

NEUTRAL AXIS

SYXTOP--- 0.99913
SYYLEFT-- 2.18580 SYYRIGHT- 3.31431
SXXBOT--- 0.77951

IXXN-- 1.11690
IYYN-- 5.43321
IXYN-- -0.91143
IUUN-- 0.93234
IVVN-- 5.61778
BETA-- -11.44761
RXXN-- 0.62613
RYYN-- 1.38098

LVTP-7 1

THE FOLLOWING SECTION PROPERTY DATA ARE
SUPPLIED BY ALCOA AS A SERVICE TO:

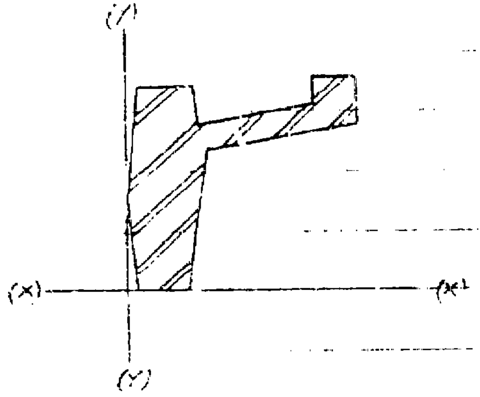
TRACK SHOE

SECT Y-Y STEEL

INPUT DATA:

I	X	Y	R	F
1	0.000	0.000	0.000	0.000
2	[illegible]	0.000	0.000	0.000
3	0.620	1.220	0.000	0.000
4	1.820	1.470	0.000	0.000
5	1.780	1.870	0.000	0.000
6	1.470	1.870	0.000	0.000
7	1.470	1.650	0.000	0.000
8	0.550	1.470	0.000	0.000
9	0.530	1.680	0.000	0.000
10	0.030	1.690	0.000	0.000
11	0.000	0.840	0.000	0.000
12	0.065	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000

SECTION NOT SYMMETRICAL ABOUT X OR Y AXIS



THE RESULTS ARE:

4.41

ARBITRARY AXIS

AREA-- 1.29620
WT/FT- ~~1.[illegible]~~
XBAR-- 0.57468
YBAR-- 1.04595
IXXA-- 1.74723
IYYA-- 0.74677
IXYA-- 0.96280

XMAX-- 1.820
XMIN-- 0.000
YMAX-- 1.870
YMIN-- 0.000

NEUTRAL AXIS

SXXTOP--- 0.39964
SYYLEFT-- 0.55424 SYYRIGHT- 0.25577
SXXBOT--- 0.31513

IXXN-- 0.32948
IYYN-- 0.31851
IXYN-- 0.18363
IUUN-- 0.50771
IVVN-- 0.14028
BETA-- -44.16433
RXXN-- 0.50404
RYYN-- 0.49557

LVTP-7 2

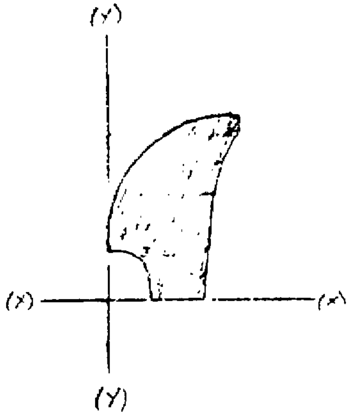
THE FOLLOWING SECTION PROPERTY DATA ARE
SUPPLIED BY ALCOA AS A SERVICE TO
TRACK SHOP
****

SECT Z-Z STEEL 11-SEP-75
****

INPUT DATA:
****

I	X	Y	R	F
1	0.000	0.000	0.000	0.000
2	0.000	0.410	0.000	0.000
3	0.375	0.410	0.000	0.375
4	0.410	0.000	0.000	0.000
5	0.812	0.000	0.000	0.000
6	0.875	0.750	0.000	0.000
7	0.906	1.050	0.000	0.000
8	1.060	1.410	0.000	0.000
9	1.060	1.530	0.000	0.000
10	1.0	1.530	0.000	0.000
11	0.000	1.530	0.000	-1.000
12	0.000	0.530	0.000	0.000
13	0.000	0.000	0.000	0.000

SECTION NOT SYMMETRICAL ABOUT X OR Y AXIS



THE RESULTS ARE:
****

35

ARBITRARY AXIS
****

AREA-- 1.02908
WT/FT- ~~1.22254~~
XBAR-- 0.53905
YBAR-- 0.77669
IXXA-- 0.77687
IYYA-- 0.35826
IXYA-- 0.45307
****
XMAX-- 1.060
XMIN-- 0.000
YMAX-- 1.530
YMIN-- 0.000

NEUTRAL AXIS
****

SXXTOP--- 0.20756
SYYLEFT-- 0.10989 SYYRIGHT- 0.11371
SXXBOT--- 0.20142

IXXN-- 0.15640
IYYN-- 0.05923
IXYN-- 0.02233
IUUN-- 0.16129
IVVN-- 0.05435
BETA-- -12.34321
RXXN-- 0.38985
RYYN-- 0.23992

LVTP-7 3

THE SUBJECT [illegible] SECTION PROPERTY DATA ARE
SUPPLIED BY [illegible]

TRACK SHOE

SECT G-0 STEEL — 17-SEP-75

INPUT DATA:

I	X	Y	R	T
1	0.000	0.000	0.000	0.000
2	0.000	0.707	0.000	0.000
3	10.500	0.707	0.000	0.000
4	10.500	0.968	0.000	0.000
5	10.000	0.968	0.000	0.000
6	10.000	0.937	0.000	0.000
7	7.250	0.937	0.000	0.000
8	7.250	0.707	0.000	0.000
9	2.375	0.707	0.000	0.000
10	2.375	0.937	0.000	0.000
11	0.000	0.937	0.000	0.000
12	0.000	0.000	0.000	0.000

SECTION SYMMETRICAL ABOUT Y AXIS

THE RESULTS ARE:

8.91

ARBITRARY AXIS

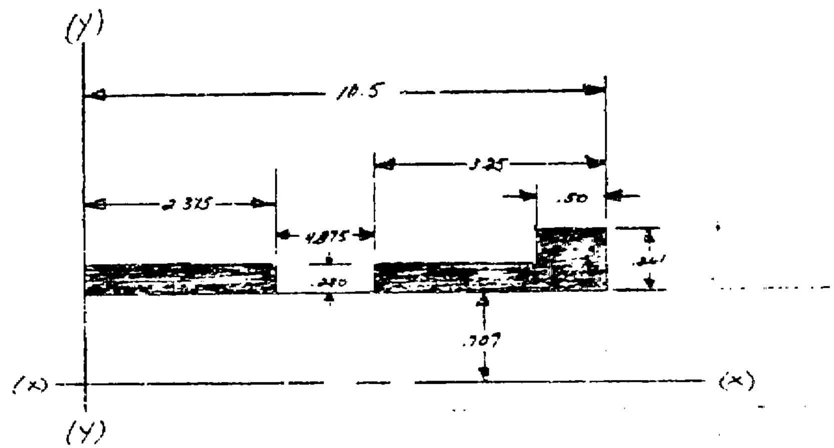
AREA-- 2.61856
WT/FT- ~~[illegible]~~
XBAR-- 0.00000
YBAR-- 0.82354
IXXA-- 1.78787
IYYA-- 124.38223
IXYA-- 0.00000

XMAX-- 10.500
XMIN-- 0.000
YMAX-- 0.968
YMIN-- 0.000

NEUTRAL AXIS

SXXTOP--- 0.08759
SYYLEFT-- 11.84593 SYYRIGHT- 11.84593
SXXBOT--- 0.01449

IXXN-- 0.01193
IYYN-- 124.38223
IXYN-- 0.00000
IUUN-- 0.01193
IVVN-- 124.38223
BETA-- 0.00000
RXXN-- 0.06750
RYYN-- 6.89217



LVTP-7 4

THE FOLLOWING SECTION PROPERTY DATA ARE
SUPPLIED BY ALCOA AS A SERVICE TO:

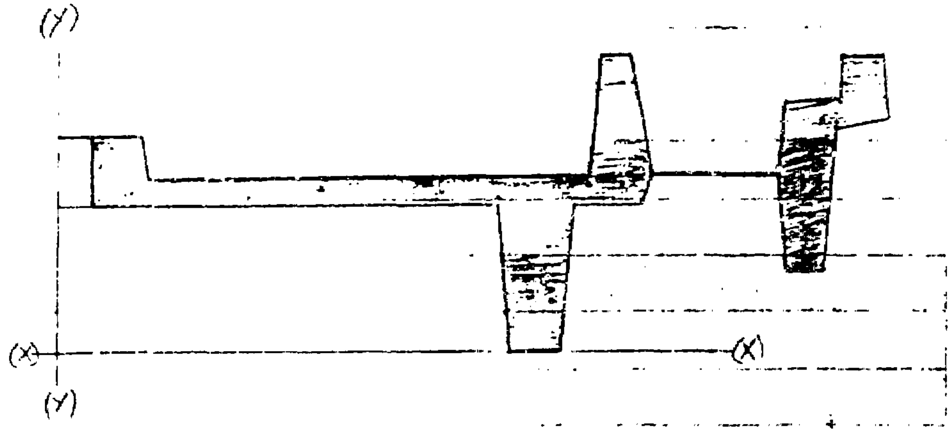
TRUCK SHOP
****

SECT A-A STEEL   11-SEP-75
****

INPUT DATA:

I	X	Y	P	F
1	0.000	0.000	0.000	0.000
2	0.000	1.280	0.000	0.000
3	3.870	1.280	0.000	0.000
4	4.000	0.000	0.000	0.000
5	4.440	0.000	0.000	0.000
6	4.570	1.280	0.000	0.000
7	5.190	1.280	0.000	0.000
8	5.250	1.530	0.000	0.000
9	6.930	1.530	0.000	0.000
10	7.000	0.690	0.000	0.000
11	7.310	0.690	0.000	0.000
12	7.430	1.920	0.000	0.000
13	7.890	2.000	0.000	0.000
14	7.840	2.560	0.000	0.000
15	7.500	2.560	0.000	0.000
16	7.500	2.180	0.000	0.000
17	7.000	2.150	0.000	0.000
18	6.930	1.530	0.000	0.000
19	5.250	1.530	0.000	0.000
20	5.060	2.560	0.000	0.000
21	4.810	2.560	0.000	0.000
22	4.720	1.510	0.000	0.000
23	0.780	1.530	0.000	0.000
24	0.760	1.840	0.000	0.000
25	0.320	1.840	0.000	0.000
26	0.320	1.280	0.000	0.000
27	0.000	1.280	0.000	0.000
28	0.000	0.000	0.000	0.000

SECTION SYMMETRICAL ABOUT Y AXIS



THE RESULTS ARE:

22.73

ARBITRARY AXIS

NEUTRAL AXIS

AREA--	6.68090		SXXTOP---	1.55541	
WT/FT-	~~[illegible]~~1	SYYLEFT--	20.28795	SYYRIGHT-	20.28795
XBAR--	0.00000		SXXBOT---	1.33790	
YBAR--	1.69028				
IXXA--	15.97315	IXX---	1.87343		

IYYA--	160.07194	IYY---	160.07194
IXYA--	0.00000	IXY---	0.00000
------------------		IUU---	1.87343
XMAX--	7.890	IVV---	160.07193
XMIN--	[illegible]	BETA--	0.00000
YMAX--	2.56	RXX---	0.52954
YMIN--	0.000	RYY---	4.89486

LVTP-7 5

THE FOLLOWING SECTION PROPERTY DATA ARE
SUPPLIED BY ALCOA AS A SERVICE FOR:

TRACY SHOE

SECT B-B STEEL 17-SEP-75

INPUT DATA:

I	X	Y	R	F
1	0.000	0.000	0.000	0.000
2	0.000	0.707	0.000	0.000
3	4.750	0.707	0.000	0.000
4	4.750	0.937	0.000	0.000
5	0.000	0.937	0.000	0.000
5	0.000	0.000	0.000	0.000

SECTION SYMMETRICAL ABOUT Y AXIS

THE RESULTS ARE:

7.43

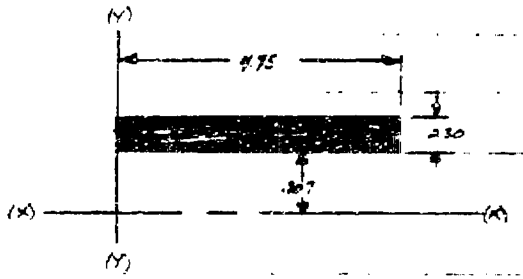
ARBITRARY AXIS

AREA--	2.18500
WT/FT-	~~[illegible]~~
XBAR--	0.00000
YBAR--	0.82200
IXXA--	1.48600
IYYA--	16.43302
IXYA--	0.00000
XMAX--	4.750
XMIN--	0.000
YMAX--	0.937
YMIN--	0.000

SYYLEFT-- 3.45958 SYYRIGHT- 3.45958

NEUTRAL AXIS

SXXTOP---	0.08376
SXXBOT---	0.01173
IXXN--	0.00963
IYYN--	16.43302
IXYN--	0.00000
IUUN--	0.00963
IVVN--	16.43302
BETA--	0.00000
RXXN--	0.06640
RYYN--	2.74241



LVTP-7 6

THE FOLLOWING SECTION PROPERTY DATA ARE
SUPPLIED BY ALCOA AS A SERVICE TO:

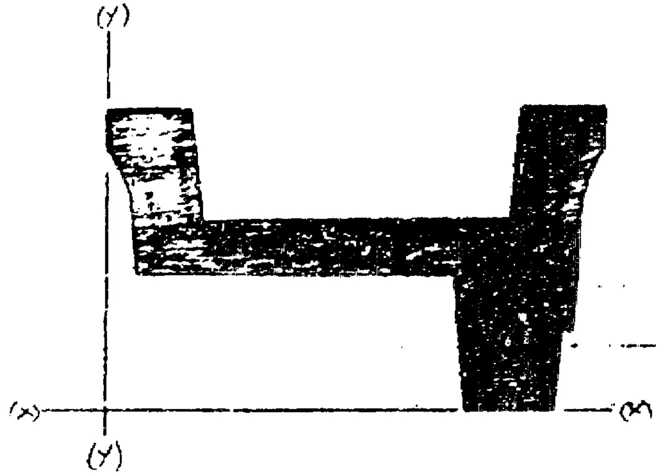
TRACK SHOP

SECT X-X ALUM   23-SEP-75

INPUT DATA:

I	X	Y	W	F
1	0.000	0.000	0.000	0.000
2	0.000	2.340	0.000	0.000
3	0.078	2.250	0.000	0.000
4	0.156	2.120	0.000	0.000
5	0.218	2.000	0.000	0.000
6	0.265	1.750	0.000	0.000
7	0.312	1.189	0.000	0.000
8	2.906	1.189	0.000	0.000
9	3.000	0.000	0.000	0.000
10	3.780	0.000	0.000	0.000
11	3.840	0.687	0.000	0.000
12	3.930	0.687	0.000	0.000
13	4.047	1.750	0.000	0.000
14	4.094	2.000	0.000	0.000
15	4.156	2.120	0.000	0.000
16	4.234	2.250	0.000	0.000
17	4.312	2.340	0.000	0.000
18	4.312	2.625	0.000	0.000
19	3.590	2.625	0.000	0.000
20	3.500	1.395	0.000	0.000
21	0.780	1.595	0.000	0.000
22	0.687	2.625	0.000	0.000
23	0.000	2.625	0.000	0.000
24	0.000	0.000	0.000	0.000

SECTION NOT SYMMETRICAL ABOUT X OR Y AXIS



THE RESULTS ARE:

ARBITRARY AXIS   NEUTRAL AXIS

AREA--   3.05037   SXXTOP---   1.33911
WT/FT-   4.58374   SYYLEFT--   2.69247   SYYRIGHT-   3.79844
XBAR--   2.52335   SXXBOT---   1.13031
YBAR--   1.42340
IXXA--   9.47716   IXXN--   1.60897
IYYA--   31.36144   IYYN--   6.79404
IXYA--   12.01103   IXYN--   -1.04800
                              IUUN--   1.40515
XMAX--   4.312   IVVN--   6.99787

XMIN--   0.000   BETA--   -11.00513
YMAX--   2.625   RXXN--   0.64576
YMIN--   0.000   RYYN--   1.52698

B-100504-AE   1

THE [illegible] SECTION PROPERTY [illegible]
[illegible]

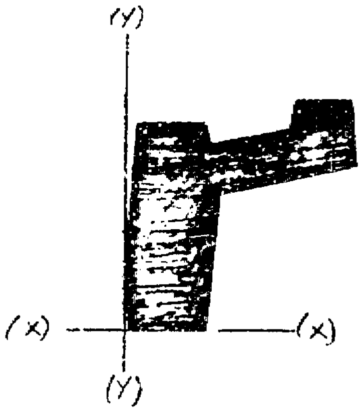
[illegible]

SECT Y-Y ALUM 14-SEP-75

INPUT DATA:

I	X	Y	R	T
1	0,000	0,000	0,100	0,000
2	0,6[illegible]	0,000	0,000	0,000
3	0,781	1,125	0,000	0,000
4	1,[illegible]	1,349	0,100	0,000
5	1,[illegible]	1,[illegible]	0,000	0,000
6	1,344	1,[illegible]	0,000	0,000
7	1,326	1,[illegible]	0,000	0,000
8	0,655	1,4[illegible]	0,000	0,000
9	0,625	1,[illegible]	0,000	0,000
10	0,030	1,[illegible]	0,000	0,000
11	0,000	0,840	0,000	0,000
12	0,060	0,000	0,000	0,000
13	0,000	0,000	0,000	0,000

SECTION NOT SYMMETRICAL ABOUT X OR Y AXIS



THE RESULTS ARE:

ARBITRARY AXIS NEUTRAL AXIS

AREA--	1,71022		SXTOP---	0,51911			
WT/FT-	2,03174	SYYLEFT--	0,67058		SYYRIGHT-	0,37604	
XBAR--	0,67905		SXXBOT---	0,41127			
YBAR--	1,04248						
IXXA--	2,[illegible]		IXXN--	0,42[illegible]			
IYYA--	1,24396		IYYN--	0,45536			
IXYA--	1,[illegible]		IXYN--	0,243[illegible]			
			IUUN--	0,14797			
XMAX--	1,890		IVVN--	0,[illegible]613			
XMIN--	0,000		BETA--	63,[illegible]			
YMAX--	1,87[illegible]		RXX---	0,50[illegible]			
YMIN--	0,000		RYY---	0,51[illegible]			

B-100504-AE 2

THE FOLLOWING SECTION PROPERTY DATA ARE
SUPPLIED BY ALCOA AS A SERVICE TO:

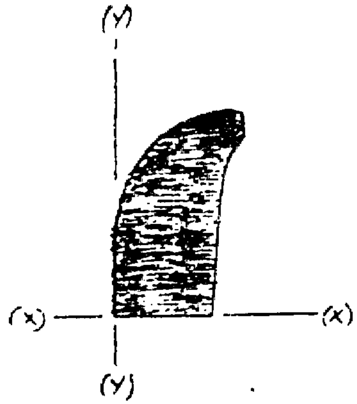
TRACK SHOE

RECT 2-2 ALUM   15-SEP-75

INPUT DATA:

I	X	Y	R	F
1	0.000	0.000	0.000	0.000
3	0.796	0.000	0.000	0.000
5	0.812	0.120	0.000	0.000
6	0.875	0.870	0.000	0.000
7	0.906	1.180	0.000	0.000
8	1.061	1.530	0.000	0.000
9	1.060	1.650	0.000	0.000
10	1.000	1.650	0.000	0.000
11	0.000	1.650	0.000	-1.000
12	0.000	0.650	0.000	0.000
13	0.000	0.000	0.000	0.000

SECTION NOT SYMMETRICAL ABOUT X OR Y AXIS



THE RESULTS ARE:

ARBITRARY AXIS

AREA--	1.26181
WT/FT-	1.49903
XBAR--	0.48943
YBAR--	0.76797
IXXA--	0.99767
IYYA--	0.38491
IXYA--	0.52870
XMAX--	1.060
XMIN--	0.000
YMAX--	1.650
YMIN--	0.000

NEUTRAL AXIS

SXXTOP--- 0.26748

SYYLEFT-- 0.16887   SYYRIGHT- 0.14486

SXXBOT--- 0.33022

IXXN--	0.25358
IYYN--	0.08265
IXYN--	0.05445
IUUN--	0.26845
IVVN--	0.06676
BETA--	-16.75135
RXXN--	0.44829
RYYN--	0.25541

B-100504-AE 3

THE FOLLOWING SECTION PROPERTY DATA ARE
SUPPLIED BY ALCOA AS A SERVICE TO:

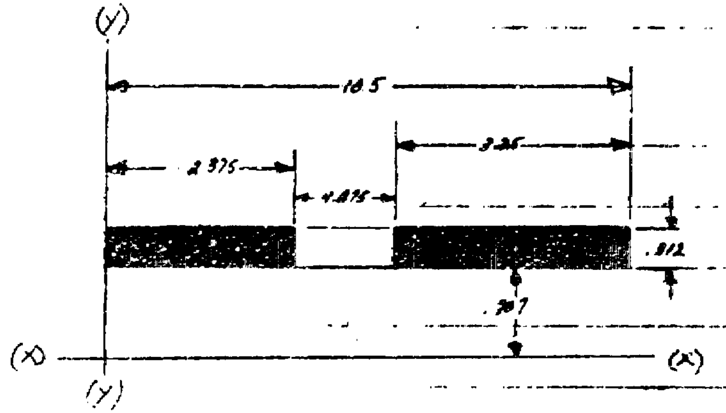
TRACK SHOE

SECT 0-0 ALUM　　　　30-SEP-75

INPUT DATA:

I	X	Y	R	T
1	0.000	0.000	0.000	0.000
2	0.000	0.707	0.000	0.000
3	10.500	0.707	0.000	0.000
4	10.500	1.019	0.000	0.000
5	7.250	1.019	0.000	0.000
6	7.250	0.707	0.000	0.000
7	2.375	0.707	0.000	0.000
8	2.375	1.019	0.000	0.000
9	0.000	1.019	0.000	0.000
10	0.000	0.000	0.000	0.000

SECTION SYMMETRICAL ABOUT Y AXIS



THE RESULTS ARE:

ARBITRARY AXIS　　　NEUTRAL AXIS

AREA--	3.51000		SXXTOP---	0.18252			
WT/FT-	4.16988	SYYLEFT--	15.54840		SYYRIGHT-	15.64940	
XBAR--	0.00000		SXXBOT---	0.03299			
YBAR--	0.86300						
IXXA--	2.64261	IXXN--	0.02847				
IYYA--	164.30821	IYYN--	164.30821				
IXYA--	0.00000	IXYN--	0.00000				
		IUUN--	0.02847				
XMAX--	10.500	IVVN--	164.30821				
XMIN--	0.000	BETA--	0.00000				
YMAX--	1.019	RXXN--	0.09007				
YMIN--	0.000	RYYN--	6.84189				

B-100504-AE　　4

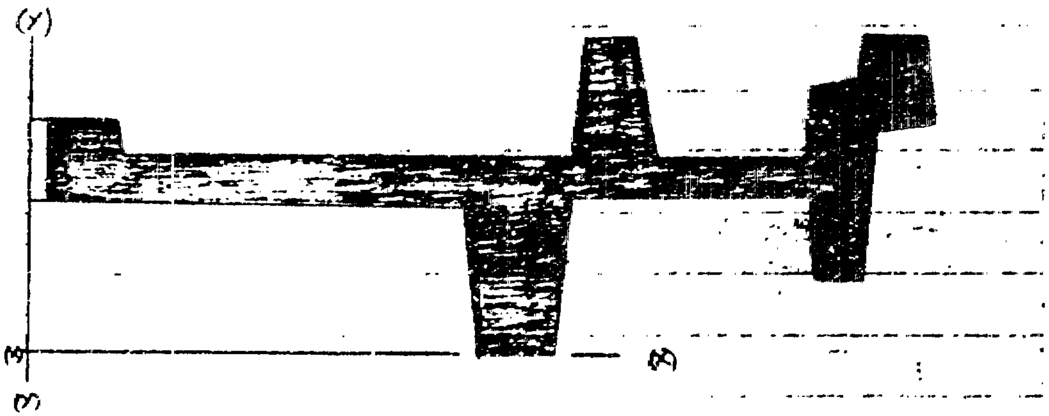
THE FOLLOWING SECTION PROPERTY DATA ARE
SUPPLIED BY ALCOA AS A SERVICE TO:

TRACK SHOE

SECT A-A ALUM   25-SEP-75

INPUT DATA:

I	X	Y	R	F
1	0.000	0.000	0.000	0.000
2	0.000	1.189	0.000	0.000
3	3.687	1.189	0.000	0.000
4	3.812	0.000	0.000	0.000
5	3.440	0.000	0.000	0.000
6	4.860	1.189	0.000	0.000
7	6.960	1.189	0.000	0.000
8	7.000	0.687	0.000	0.000
9	7.430	0.687	0.000	0.000
10	7.560	1.670	0.000	0.000
11	7.937	1.937	0.000	0.000
12	7.870	2.625	0.000	0.000
13	7.310	2.625	0.000	0.000
14	7.280	2.187	0.000	0.000
15	7.030	2.156	0.000	0.000
16	6.960	1.595	0.000	0.000
17	5.156	1.595	0.000	0.000
18	5.060	2.625	0.000	0.000
19	4.650	2.625	0.000	0.000
20	4.560	1.595	0.000	0.000
21	0.703	1.595	0.000	0.000
22	0.407	1.810	0.000	0.000
23	0.328	1.810	0.000	0.000
24	0.328	1.189	0.000	0.000
25	0.000	1.189	0.000	0.000
26	0.000	0.000	0.000	0.000



SECTION SYMMETRICAL ABOUT Y AXIS

THE RESULTS ARE:

ARBITRARY AXIS   NEUTRAL AXIS

AREA--	10.66869		SXXTOP---	2.32938			
WT/FT-	12.67440	SYYLEFT--	34.20779		SYYRIGHT-	34.20779	
XBAR--	0.00000		SXXBOT---	2.01522			
YBAR--	1.40741						
IXXA--	23.96877		IXXN--	2.83624			
IYYA--	271.50723		IYYN--	271.50723			
IXYA--	0.00000		IXYN--	0.00000			

		IUUN--	2.83624
XMAX--	7.937	IVVN--	271.50723
XMIN--	0.000	META--	0.00000
YMAX--	2.625	RXXN--	0.51560
YMIN--	0.000	RYYN--	5.04470

B-100504-AE   5

THE FOLLOWING SECTION PROPERTY DATA ARE
SUPPLIED BY ALCOA AS A SERVICE TO:

TRACK SHIP

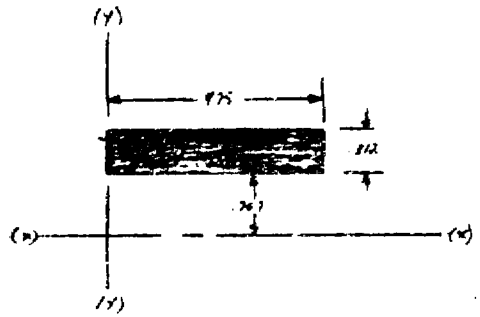
****

SECT R-R ALUM 17-SEP-75

INPUT DATA:

I	X	Y	R	F
1	0.000	0.000	0.000	0.000
2	0.000	0.707	0.000	0.000
3	4.750	0.707	0.000	0.000
4	4.750	1.019	0.000	0.000
5	0.000	1.019	0.000	0.000
6	0.000	0.000	0.000	0.000

SECTION SYMMETRICAL ABOUT Y AXIS



THE RESULTS ARE:

ARBITRARY AXIS

AREA--	2.96400
WT/FT-	3.57123
XBAR--	0.00000
YBAR--	0.86300
IXXA--	2.23154
IYYA--	22.29175
IXYA--	0.00000
XMAX--	4.750
XMIN--	0.000
YMAX--	1.019
YMIN--	0.000

NEUTRAL AXIS

SYYLEFT-- 4.69300 SXXTOP--- 0.15413 SYYRIGHT- 4.69300
SXXBOT--- 0.02786

IXXN--	0.02404
IYYN--	22.29175
IXYN--	0.00000
IULN--	0.02404
IVVN--	22.29175
BETA--	0.00000
RXXN--	0.09007
RYYN--	2.74241

B-100504-AE 6

[illegible]

[illegible] SHOE 2

****

SECT [illegible]   17-[illegible]-75

INPUT DATA:

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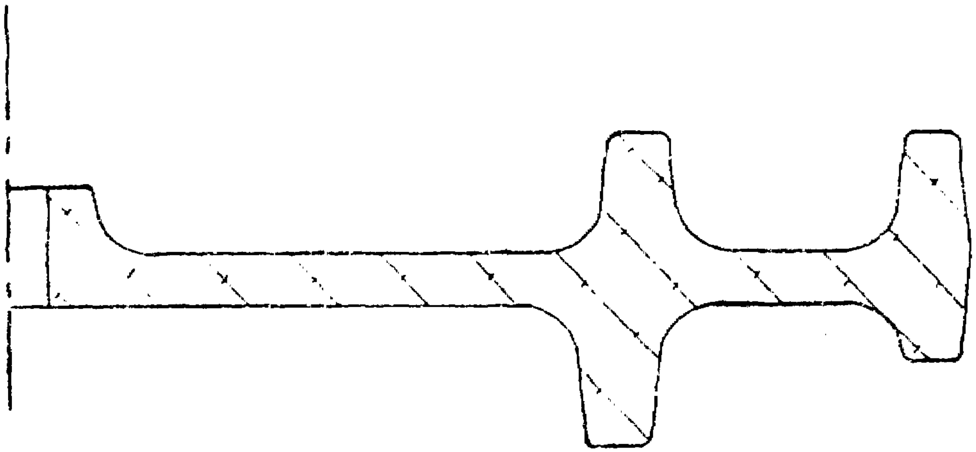
4	4.610	0.000	0.000	0.000
5	5.[illegible]	0.000	0.000	0.000
6	5.470	1.189	0.000	0.000
7	7.44[illegible]	1.189	0.000	0.000
8	7.550	0.689	0.000	0.000
9	7.940	0.[illegible]	0.000	0.000
10	[illegible]	1.330	0.000	0.000
11	7.[illegible]	2.625	0.000	0.000
12	7.550	2.625	0.000	0.000
13	7.430	1.595	0.000	0.000
14	5.420	1.595	0.000	0.000
15	[illegible]	2.625	0.000	0.000
16	5.010	2.625	0.000	0.000
17	4.910	1.595	0.000	0.000
18	0.650	1.595	0.000	0.000
19	0.555	2.219	0.000	0.000
20	0.310	2.219	0.000	0.000
21	0.331	1.189	0.000	0.000
22	0.300	1.189	0.000	0.000
23	0.300	0.300	0.000	0.000



SECTION SYMMETRICAL ABOUT Y AXIS

THE RESULTS ARE:

ARBITRARY AXIS   CENTRAL AXIS

AREA=	11.0[illegible]		[illegible]=	2.2547[illegible]		
WT/FT=	13.1[illegible]	SY[illegible]=	[illegible].57[illegible]		SY[illegible]=	[illegible].57[illegible]
THI[illegible]=	0.0000[illegible]		[illegible]=	1.[illegible]		
YA[illegible]=	1.42[illegible]					
I[illegible]=	2[illegible]		I[illegible]=	2.[illegible]		
I[illegible]=	311.[illegible]		I[illegible]=	311.[illegible]		
I[illegible]=	[illegible]		I[illegible]=	0.00000		
			I[illegible]=	2.70207		
[illegible]=	[illegible]		I[illegible]=	311.33549		
[illegible]=	[illegible]		[illegible]=	0.00000		

[illegible]=	2.[illegible]	[illegible]=	[illegible]
[illegible]=	[illegible]	[illegible]=	[illegible]

B-100508-AE   1

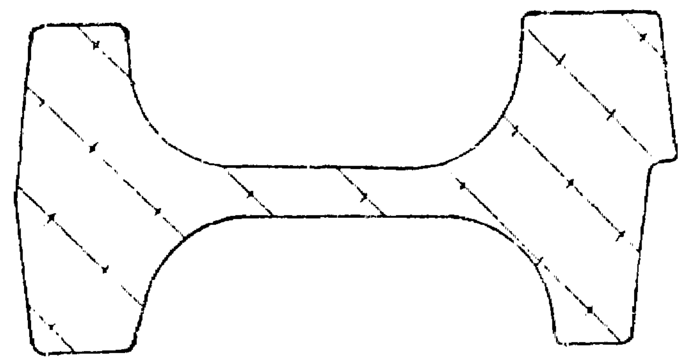
[illegible] SECTION PROPERTY DATA ARE
[illegible] SERVICE [illegible]

TRACK SHOE 2

SECT [illegible] ALUM 20-OCT-75

INPUT DATA:

I	X	Y	R	F
1	0.000	0.000	0.000	0.000
2	0.000	1.060	0.000	0.000
3	0.093	0.000	0.000	0.000
4	0.812	0.000	0.000	0.000
5	0.906	0.843	0.000	0.000
6	3.593	0.843	0.000	0.000
7	3.656	0.000	0.000	0.000
8	4.187	0.000	0.000	0.000
9	4.310	1.290	0.000	0.000
10	4.368	1.280	0.000	0.000
11	4.468	2.280	0.000	0.000
12	3.468	2.280	0.000	0.000
13	3.375	1.249	0.000	0.000
14	0.906	1.249	0.000	0.000
15	0.912	2.280	0.000	0.000
16	0.093	2.280	0.000	0.000
17	0.000	1.060	0.000	0.000
18	0.000	0.000	0.000	0.000



SECTION NOT SYMMETRICAL ABOUT X OR Y AXIS

THE RESULTS ARE:

ARBITRARY AXIS

AREA--	6.42681
WT/FT-	5.73425
XBAR--	2.20651
YBAR--	1.17570
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	13.[illegible]
XMB---	4.[illegible]
YMT---	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

[illegible] AXIS

SYXTOP---	1.42415		
SYYLEFT--	5.[illegible]	SYYRIGHT-	5.39692
SXYBOT---	1.33265		
[illegible]	1.57268		
[illegible]	12.[illegible]		
[illegible]	0.5[illegible]		
[illegible]	1.54[illegible]		
IYY---	12.22942		
BETA---	2.73726		
[illegible]	[illegible]		
[illegible]	1.5[illegible]		

B-100508-AE 2

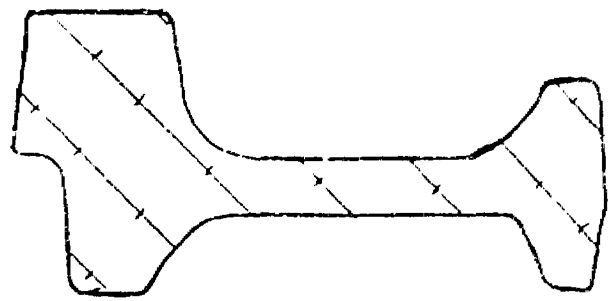
THE ... PROPERTY DATA ARE
SUPPLIED ... AS A SERVICE THE

TRACK SHOE 2

SECT Y-Y ALUM 17-OCT-75

INPUT DATA:

I	X	Y	R	F
1	0.000	0.000	0.000	0.000
2	0.000	0.937	0.000	0.000
3	0.187	0.937	0.000	0.000
4	0.280	0.000	0.000	0.000
5	0.812	0.000	0.000	0.000
6	0.875	0.500	0.000	0.000
7	3.468	0.500	0.000	0.000
8	3.500	0.000	0.000	0.000
9	3.875	0.000	0.000	0.000
10	3.930	0.703	0.000	0.000
11	3.875	1.406	0.000	0.000
12	3.500	1.406	0.000	0.000
13	3.468	0.906	0.000	0.000
14	1.078	0.906	0.000	0.000
15	0.980	1.930	0.000	0.000
16	0.000	1.930	0.000	0.000
17	0.000	0.000	0.000	0.000



SECTION NOT SYMMETRICAL ABOUT X OR Y AXIS

THE RESULTS ARE:

ARBITRARY AXIS / NEUTRAL AXIS

AREA--	3.25957		SXXTOP---	0.65266		
WT/FT-	3.97237	SYYLEFT--	3.36578		SYYRIGHT-	2.39981
XBAR--	1.63579		SXXBOT---	0.76067		
YBAR--	0.89112					
IXXA--	3.26546		IXXN--	0.67803		
IYYA--	14.22764		IYYN--	5.50569		
IXYA--	4.05562		IXYN--	-0.49561		
			IUU--	0.57971		
XMAX--	3.930		IVV--	5.60397		
XMIN--	0.000		BETA--	-8.04008		
YMAX--	1.930		RXX--	0.45608		
YMIN--	0.[illegible]		RYY--	1.29965		

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APPENDIX C

DRIVE LOAD ANALYSIS

I. SINGLE PIN, CONCEPTS 1 AND 4

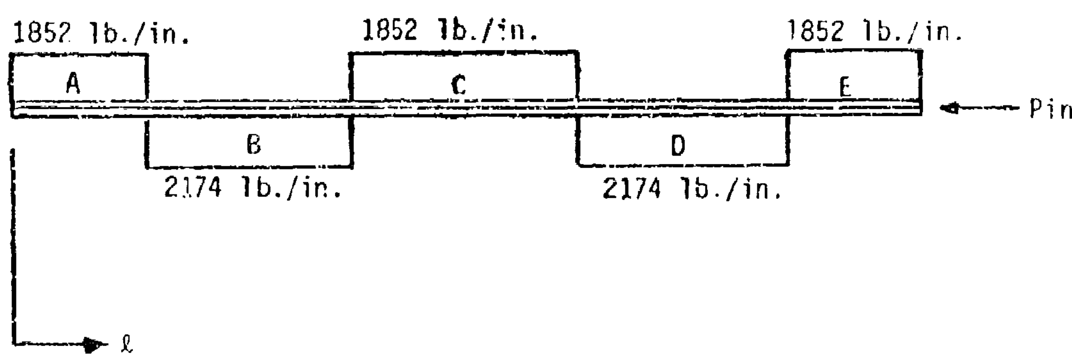
This analysis specifically addresses Concept 1, single pin with end drive (Drawing B-100504-AE). The section properties are those described in Appendix B. Because of block design similarity with the drive insert single-pin concept (4), this analysis generally applies to both single-pin concepts 1 and 4, except for the drive area itself.

A. Track Tension Loading

Track operating conditions:

20,000 lbs. tension
67,000 in.-lb. torsion

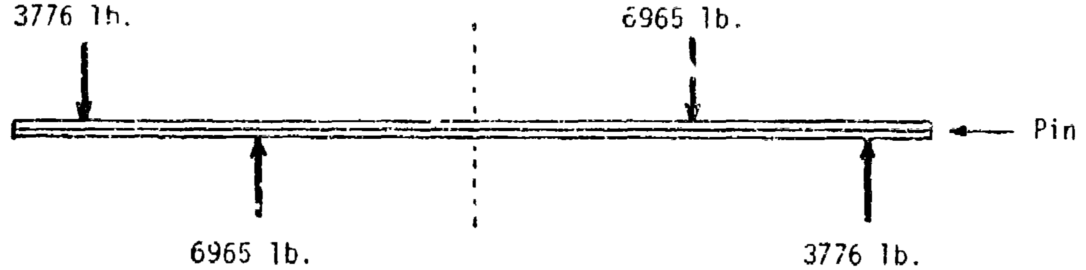
Tension loading:



These loads are analyzed by assuming concentrated loads applied at the "hinge" locations, as below:

A	-	5,740 lbs.	at ℓ =	1.55"
B	-	10,000 lbs.	at ℓ =	5.61"
C	-	8,520 lbs.	at ℓ =	10.42"
D	-	10,000 lbs.	at ℓ =	15.23"
E	-	5,740 lbs.	at ℓ =	19.29"

B. Track Torsional Loading

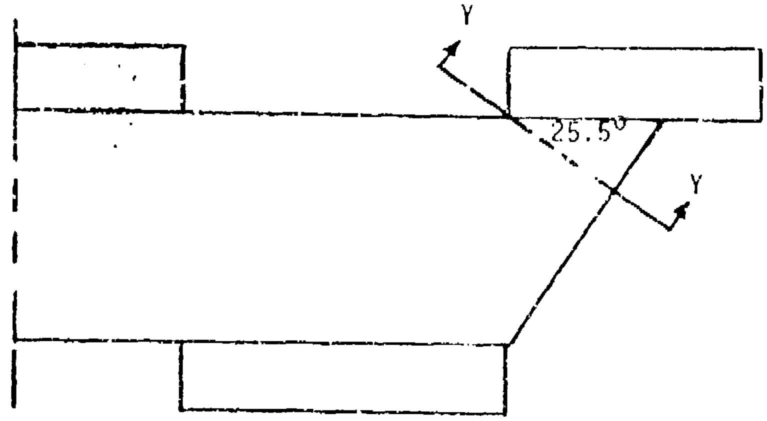


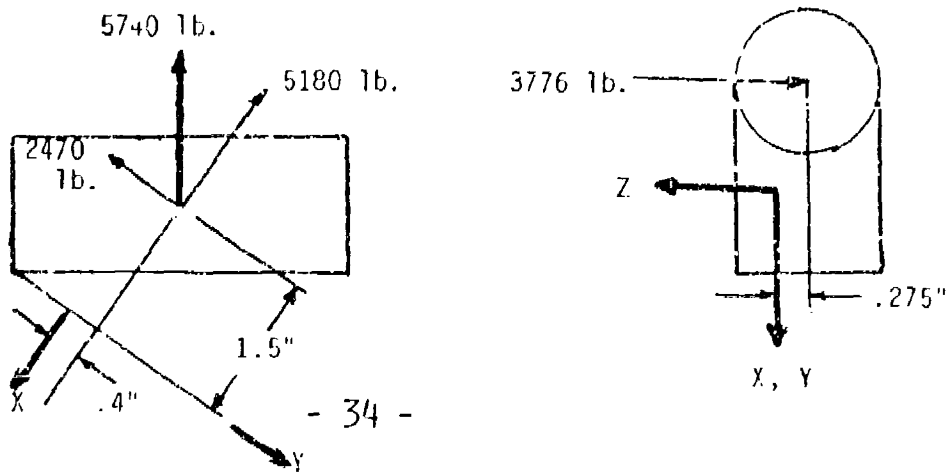
Assume the 67,000 in.-lb. moment about the track center is composed of concentrated loads acting at same locations as tensile loads, as indicated below.

3,776 lbs. at ℄ = 1.55" and 19.29"
6,965 lbs. at ℄ = 5.61" and 15.23"

C. Stress on End Drive Location of Track Body, Section Y-Y, Concept 1

Refer to drawing B-100504-AE. Section Y-Y is included at an angle of 25.5° to the pin as shown in the sketch below:





Stress conditions for the 67,000 in.-lb. torsional loads applied positive (as shown) and negative are calculated below:

+ 67,000 in.-lb. Torsion:

$$M_x = 3{,}776\ (.4) + 2{,}470\ (.275)$$
$$= 2{,}190 \text{ in.-lb.}$$

$$M_y = 3{,}776\ (1.5) - 5{,}180\ (.275)$$
$$= 4{,}240 \text{ in.-lb.}$$

$$M_z = -2{,}470\ (1.5) - 5{,}180\ (.4)$$
$$= -5{,}777 \text{ in.-lb.}$$

R_x = 5,180 lb.
R_y = 2,470 lb.
R_z = 3,776 lb.

- 67,000 in.-lb. Torsion:

$$M_x = -3{,}776\ (.4) + 2{,}470\ (.275)$$
$$= -\ 830 \text{ in.-lb.}$$

$$M_y = -3{,}776\ (1.5) - 5{,}180\ (.275)$$
$$= -7{,}090 \text{ in.-lb.}$$

$$M_z = -2{,}470\ (1.5) - 5{,}180\ (.4)$$
$$= -5{,}777 \text{ in.-lb.}$$

Bending and tensile stresses are then determined using the section properties shown in Appendix B for Section Y-Y.

$$\sigma \text{ Bending} = \frac{Mc}{I} \qquad \sigma \text{ Tensile} = \frac{P}{A}$$

+ 67,000 in.-lb. Torsion:

$$\sigma \text{ B-Top} = \frac{-4{,}240\ (1.87-1.042)}{.42874} = -8{,}190 \text{ psi}$$

$$\sigma \text{ B-Bottom} = \frac{4{,}240\ (1.042)}{.42874} = 10{,}300 \text{ psi}$$

$$\sigma \text{ B-Inside} = \frac{-5{,}777\ (.68)}{.45536} = -8{,}630 \text{ psi}$$

$$\sigma \text{ B-Outside} = \frac{-5{,}777\ (.68-1.89)}{.45536} = 15{,}350 \text{ psi}$$

$$\sigma \text{ Tensile} = \frac{5{,}180}{1.7102} = 3{,}030 \text{ psi}$$

- 67,000 in.-lb. Torsion:

$$\sigma \text{ B-Top} = \frac{-7,090\ (1.042-1.87)}{.42874} = 13,690 \text{ psi}$$

$$\sigma \text{ B-Bottom} = \frac{-7,090\ (1.042)}{.42874} = -17,230 \text{ psi}$$

$$\sigma \text{ B-Inside} = \frac{-5,777\ (.68)}{.45536} = -8,630 \text{ psi}$$

$$\sigma \text{ B-Outside} = \frac{-5,777\ (.68-1.89)}{.45536} = 15,350 \text{ psi}$$

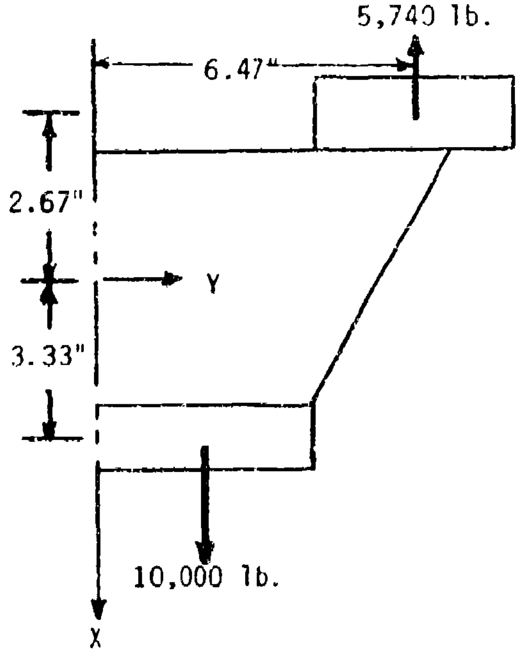
$$\sigma \text{ Tensile} = \frac{5,180}{1.7102} = 3,030 \text{ psi}$$

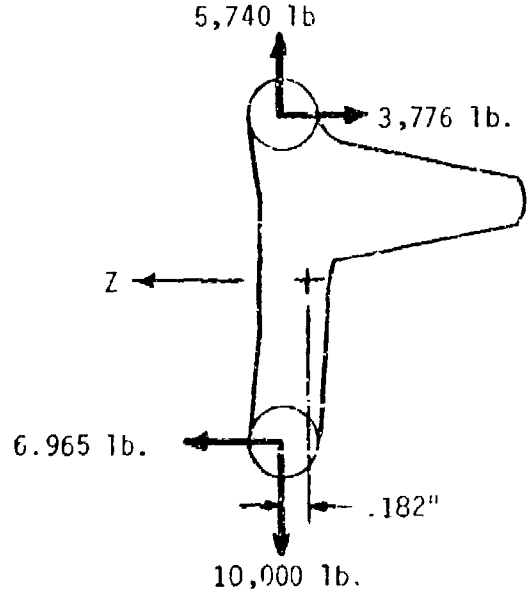
The worst stress condition in this section is then at the top, outside element where

$$\sigma \text{ Maximum} = 3,030 + 15,350 + 13,690 = 32,070 \text{ lbs.}$$

This results in a factor of safety of 1.75 based on the typical yield strength of 2014-T6 die forgings. The life of this design is not infinite as indicated by this stress condition above the material's endurance limit (18,000 psi). Estimates of lifetime are not felt to be accurate within the scope of this analysis and are not made. Additional strengthening of this design might be indicated after a more precise determination of stress patterns (particularly stress concentrations) is made (e.g. by laboratory stress analysis as suggested in Section V).

D. Stresses Through Track Block, Section X-X





$$M_x = \pm 3{,}776\ (6.47) \mp 6{,}965\ (2.41)$$
$$= \pm 7{,}645 \text{ in.-lb. } (\pm \text{ torsion load})$$

$$M_y = 5{,}740\ (.182) \pm 3{,}776\ (2.67) \pm 6{,}965\ (3.33) - 10{,}000\ (.182)$$
$$= 32{,}500 \text{ in.-lb. } (+ \text{ torsion})$$
$$= -34{,}050 \text{ in.-lb. } (- \text{ torsion})$$

$$M_z = 10{,}000\ (2.41) - 5{,}740\ (6.47)$$
$$= -13{,}040 \text{ in.-lb.}$$

$$R_x = 5{,}740 - 10{,}000$$
$$= -4{,}260 \text{ lb.}$$

$$R_y = 0$$

$$R_z = 3{,}776 - 6{,}965 = \mp 3{,}190\ (\pm \text{ torsion})$$

$$\sigma \text{ Bending} = \frac{Mc}{I}$$

$$\sigma \text{ B-Top} = \frac{7{,}645\ (1.202)}{1.609}$$
$$= \pm 5{,}710 \text{ psi } (\pm \text{ torsion})$$

$$\sigma \text{ B-Bottom} = \frac{7{,}645\ (1.423)}{1.609}$$
$$= \mp 6{,}760 \text{ psi } (\pm \text{ torsion})$$

$$\sigma \text{ B-Front} = \frac{-13{,}040\ (1.789)}{6.794}$$
$$= -3{,}430 \text{ psi } (\pm \text{ torsion})$$

$$\sigma \text{ B-Rear} = \frac{13{,}040\ (2.523)}{6.794}$$
$$= 4{,}840 \text{ psi } (\pm \text{ torsion})$$

Tension loads normal to track surface are zero so that the worst stresses are at the top rear surface of the block, and are 10,550 psi; a safety factor of more than 5 over the typical yield strength of 2014-T61. Thus, Section X-X is adequate from the standpoint of gross stress levels; possible stress concentrations should be defined in laboratory tests of prototype hardware.

E. Stress through track block assuming one block supports the entire vehicle weight (Section A-A).

Beam Loading:

$$M \text{ maximum} = \frac{PL}{4}$$
$$= \frac{(6)\ (50{,}000)}{4}$$
$$= 75{,}000 \text{ in.-lb.}$$

$$\sigma \text{ Bending} = \frac{Mc}{I}$$

$$\sigma \text{ B-Bottom} = \frac{(75)\ (1.407)}{2\ (2.836)}$$
$$= -18,600 \text{ psi}$$

$$\sigma \text{ B-Top} = \frac{(75)\ (1.218)}{2\ (2.836)}$$
$$= 16,100 \text{ psi}$$

Stresses are well within 2014-T61 yield strength with a safety factor of approximately 3 for this extreme loading condition.

II. Single Pin, Concept 2

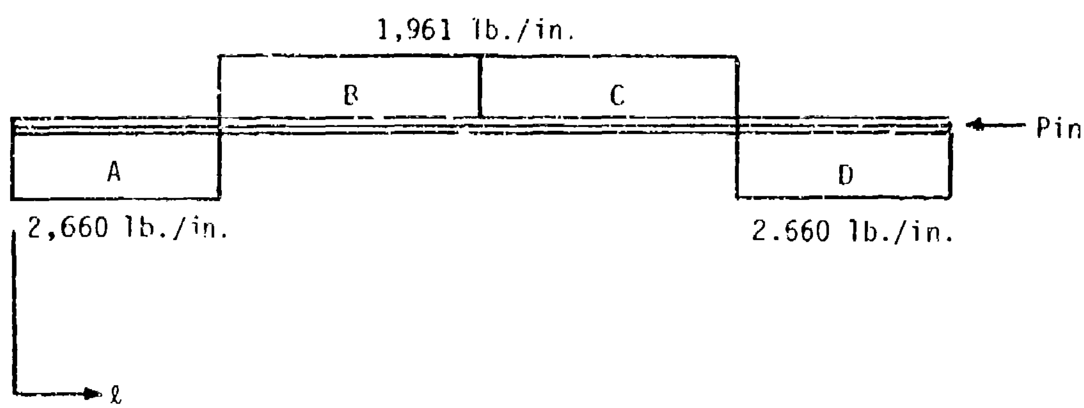
Refer to Drawing B-100508-AE

A. Track Tension Loading

Track operating conditions:

20,000 lbs. tension
67,000 in-lb. torsion

Tension loading:



Assume concentrated loads at "hinge" locations:

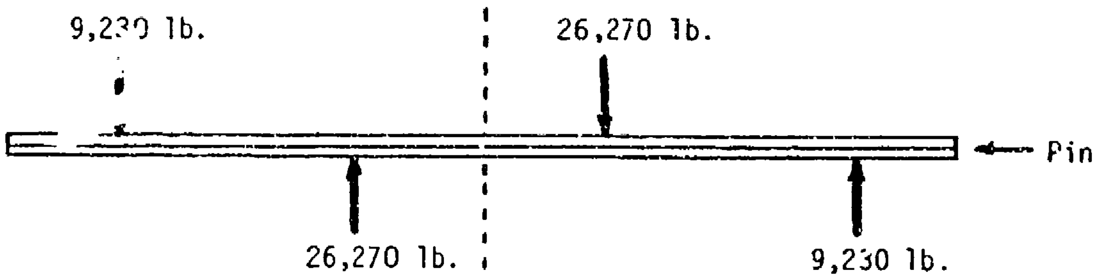
A - 10,000 lbs. at ℓ = 1.96
B - 10,000 lbs. at ℓ = 6.67
C - 10,000 lbs. at ℓ = 11.77
D - 10,000 lbs. at ℓ = 16.48

Appendix C - Continued

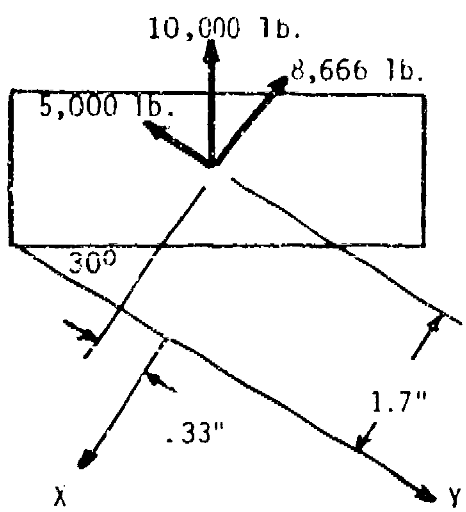
B. Track Torsional Loading.

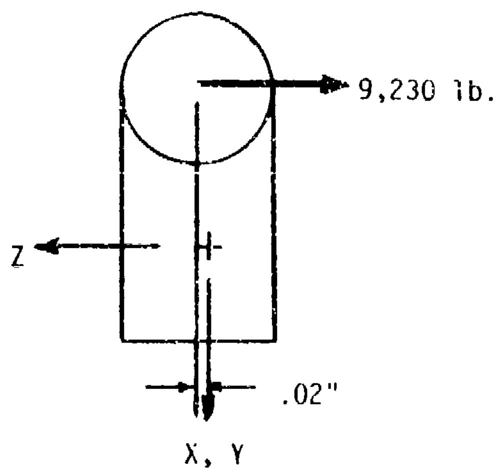
The 67,000 in.-lb. torsional load is composed of concentrated loads acting at the same locations as above.

9,230 lbs. at ℓ = 1.96 and 16.48
26,270 lbs. at ℓ = 6.67 and 11.77



C. Stress on End Drive Location of Track Body, Section Y-Y, Concept 2





$Rx = 8,660$ psi

$Ry = 5,000$ psi

$Rz = \pm 9,230$ psi (± torsion)

$Mx = -9,230\ (.33) = \mp 11,710$ psi (± torsion)

$My = 9,230\ (1.7) = \pm 15,690$ psi (± torsion)

$Mz = 8,660\ (.33) - 5,000\ (1.7) = -5,640$ psi

$$\sigma \text{ Tension} = \frac{P}{A} = \frac{8,660}{3.259} = 2,660 \text{ psi}$$

$$\sigma \text{ Top} = \frac{Mc}{I} = \frac{\pm(15.69)\ (1.04)}{.678} = \pm 24,000 \text{ psi}$$

$$\sigma \text{ Bottom} = \frac{Mc}{I} = \frac{\pm(15.69)\ (.8911)}{.678} = \pm 20,620 \text{ psi}$$

$$\sigma \text{ Front} = \frac{Mc}{I} = \frac{-(5.64)\ (1.636)}{5.5057} = -1,680 \text{ psi}$$

$$\sigma \text{ Rear} = \frac{Mc}{I} = \frac{(5.64)\ (2.294)}{5.5057} = 2,350 \text{ psi}$$

The worst stress condition is at top, rear

$$\sigma = 2,660 + 24,000 + 2,350 = 29,010 \text{ psi}$$

This is a safety factor of approximately 1.9 on yielding for typical 2014-T61 properties, but as in the case of Concept 1, the life of the design is not infinite. Further fatigue evaluation is left to laboratory stress analysis.

General comment -- Caution is advised in the interpretation of the calculations shown in this Appendix. The bending formula $\sigma = \frac{Mc}{I}$ assumes that the cross sectional dimensions of the beams are small compared to their lengths. Stresses could be larger than indicated, particularly at stress concentrations. These values are shown to suggest areas (such as the centerguide and end drive location) that might require additional strengthening. The sections are based on the LVTP-7 track (Appendix B) and are generally such that the aluminum track will be equal to the existing steel track. Final design refinement by laboratory stress analysis should be completed, as indicated in Section V.

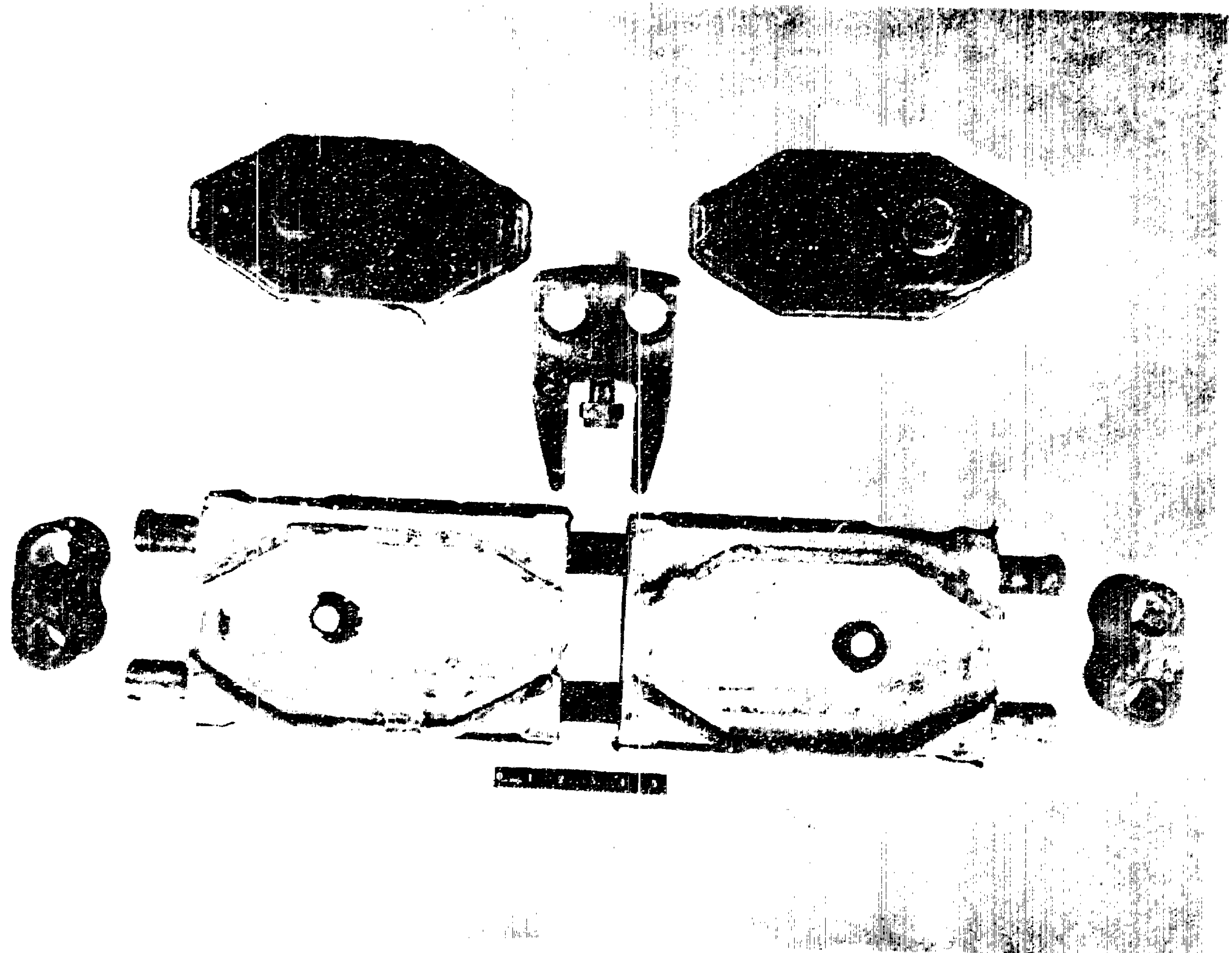


Figure 1. Aluminum T-142 Double-Pin Track. Single-piece alloy 2014-T61 forgings replace the standard production three-piece steel track blocks at a weight savings of 16.7 lbs. per pitch (assembled track shoe), a reduction of 22 percent. The production pins, end connectors, centerguide, and pads are used; the track is completely interchangeable with the steel T-142 and T-97 tracks presently used on the M48 and M60 vehicles.

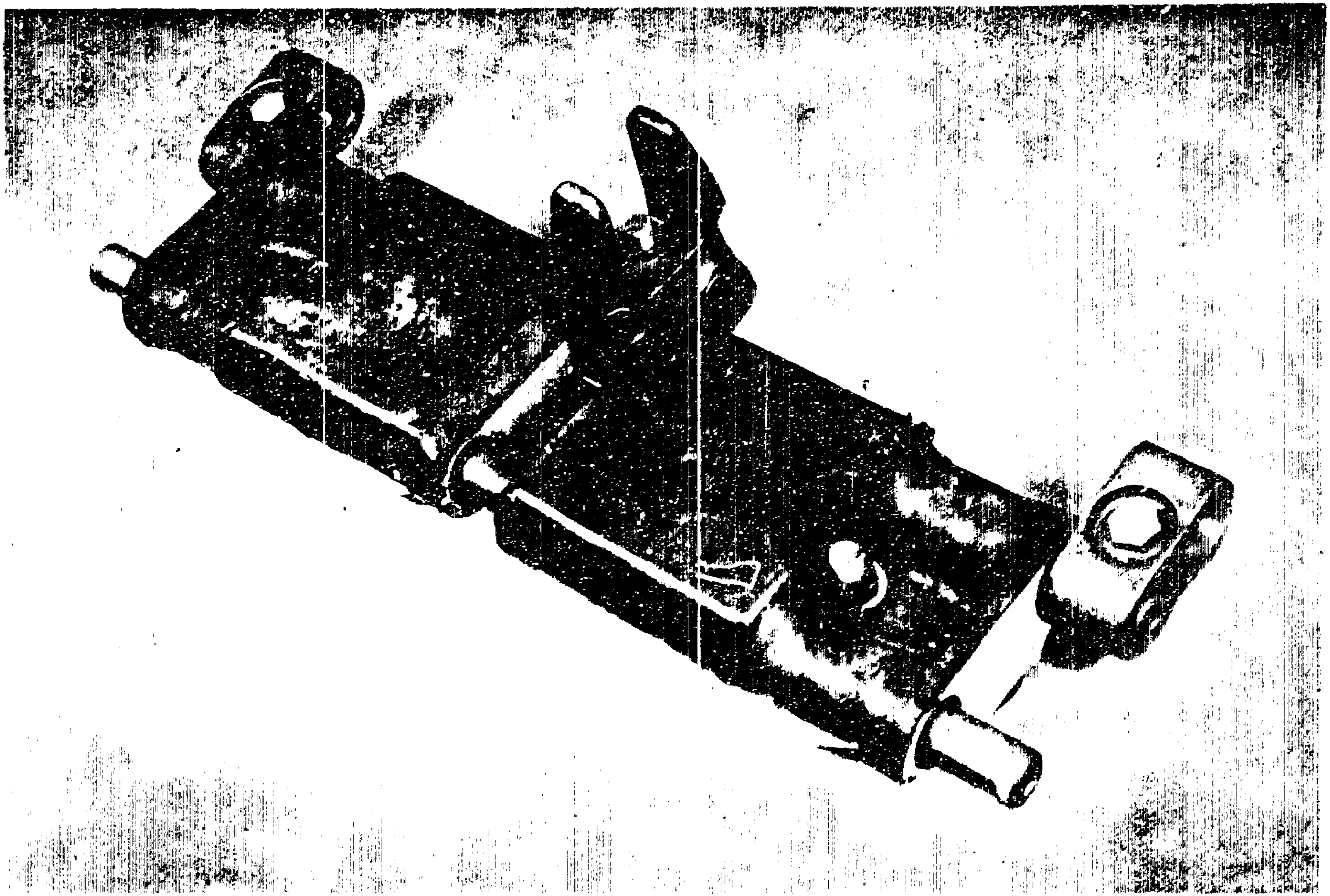


Figure 2. One Complete Pitch (Track Shoe Assembly) of the Aluminum T-142 Track. Track width, 28 inches; pitch, 6.937 inches; weight, 59.9 lbs. Roadwheel side rubber is molded to the aluminum blocks; road surface pads are replaceable.

Figure 3. Half Section of the T-144 Double-Pin Track Used on M501 Hawk Missile Loader Vehicle (sectioned through the centerguide). Track block is 2014-T6 aluminum forging encased in molded rubber. Steel protective cap for integral centerguide is bonded to the aluminum "horn" by the rubber casing.

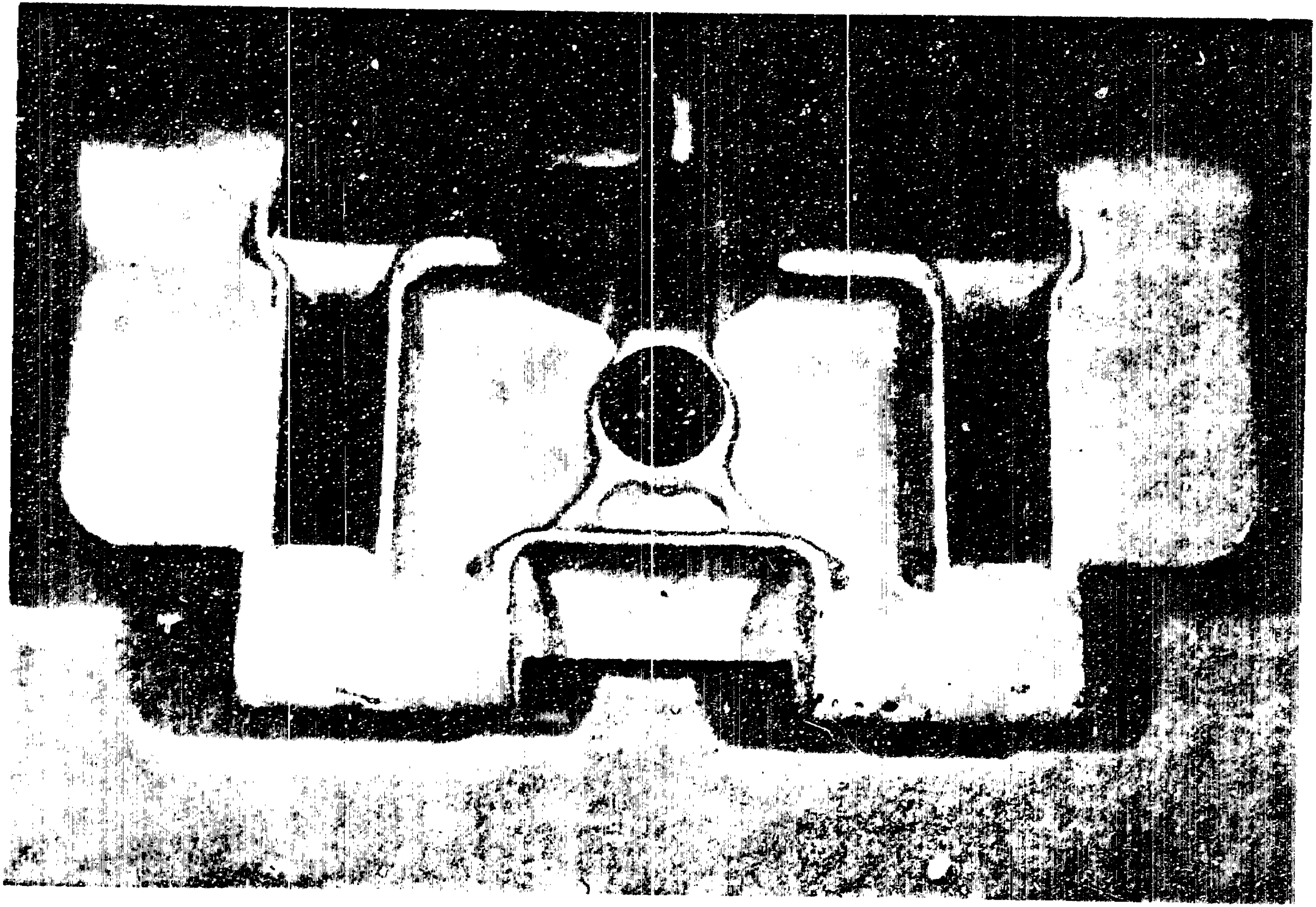


Figure 4. Single-Pin T-130 Track (M113 Personnel Carrier). Shown is an aluminum casting for laboratory stress analysis of the production steel T-130 track shoe. The integral centerguide and drive area in the track body are typical of single-pin designs.

Forging Alloys - Characteristics and Uses

Alloy	Tempers generally used	General Characteristics	Typical Uses
1100	-0	Commercially pure aluminum not susceptible to heat treatment. Easily forged. Excellent resistance to corrosion.	Cooking utensil components; pipe fittings and other parts for chemical equipment. Cable clamps for electrical industry.
2014	-T6 -T61	High tensile and yield strength combined with good ductility. Good machinability. Fair forging characteristics.	Widely used for aircraft and other heavy-duty structural uses. For forgings of very large cross section, the alloy can be rough machined in F temper and then heat treated to obtain somewhat higher properties and alleviate distortion problems. Actual uses include airframe components, aircraft landing gear parts, truck wheel hubs, equalizer beams for trucks, ordnance and missile parts.
2024	-T6	Special purpose alloy not used for general forging applications. High strength but relatively poor forging characteristics.	Aircraft propellers.
2219	-T6 -T852	Good mechanical properties at room temperatures. Ability to retain strength after prolonged exposure at elevated temperature. Very good weldability and joint efficiency.	Tankage for liquid fuel rockets. Structural parts which must operate at elevated temperature for prolonged periods. Structural parts to be welded.
2618	-T61	Good mechanical properties at elevated temperature. Freedom from growth.	Aircraft cylinder heads and pistons. Tire molds. Jet engine accessories.
4032	-T6	Good elevated temperature strength. Lowest coefficient of expansion of forging alloys.	Forged pistons.
5083	-H111 -H112 -H117 -H131 -H321	High strength nonheat treatable alloy. Strengthened by cold working. Good for ballistic applications. Very good weldability. Good corrosion resistance.	Ballistic parts for military vehicles. Welded high strength structures. Marine applications.
5456	-H111 -H112 -H116/117 -H131 -H321	Similar to 5083. Slightly higher strength.	Ballistic parts for military vehicles. Welded high strength structures. Marine applications.

Figure 5

Alloy	Tempers generally used	General Characteristics	Typical Uses
6061	-T6 -T652	Moderate yield and tensile strength combined with good ductility. Excellent forging characteristics.	Transportation equipment such as truck parts and automotive wheels, pipe flanges; chemical industry and water heater hardware requiring assembly by welding or brazing.
6151	-T6 -T652	Moderate mechanical properties. Good machining characteristics and resistance to corrosion. Excellent forging characteristics.	Intricate parts, aircraft engines, crankcases, automotive parts and hardware, machinery parts such as spool heads and spinning buckets for textile industry, trowel handles.
7075	-T6 -T652 -T73 -T7352	High strength aluminum forging alloy. Close control required in fabrication. Overaged (-T7) tempers have high resistance to stress-corrosion cracking. Tensile and yield strengths are about 10% less than 7075-T6.	Aerospace applications. Typical uses are airframe parts, landing gear and undercarriage parts. Structural parts requiring high resistance to stress corrosion cracking use overaged tempers.

Figure 5 - Continued

ALCOA FORGING ALLOY DATA

TYPICAL PHYSICAL PROPERTIES—ALUMINUM FORGING ALLOYS

Alloy and temper	Density lb/cu in.	Melting range approximate °F	Electrical conductivity percent of International Annealed Copper Standard	Thermal conductivity at 25°C, CGS units
2014-T4	0.1012	950-1180	34	0.32
2014-T6	0.1012	950-1180	40	0.37
2014-T61	0.1012	950-1180	40	0.37
2024-T852	0.1005	935-1180	38	0.36
2219-T6	0.1023	1010-1190	32	0.30
2219-T852	0.1023	1010-1190	32	0.30
2618-T61	0.0999	1040-1185	39	0.36
4032-T6	0.0966	990-1060	35	0.33
5083-H111	0.0961	1075-1185	29	0.28
5083-H112	0.0961	1075-1185	29	0.28
5083-H131	0.0961	1075-1185	29	0.28
6061-T6	0.0976	1100-1205	43	0.40
6061-T652	0.0976	1100-1205	43	0.40
6051-T6	0.0977	1090-1200	45	0.41
6151-T652	0.0977	1090-1200	45	0.41
7075-T6	0.1013	890-1175	33	0.31
7075-T652	0.1013	890-1175	33	0.31
7075-T73	0.1013	890-1175	40	0.35
7075-T7352	0.1013	890-1175	40	0.36

Average Coefficient of Thermal Expansion—Aluminum Forging Alloys[1]

Alloy	Temperature Range			
	-58° to 68°F	68° to 212°F	68° to 392°F	68° to 572°F
2014	11.7	12.5	13.1	13.6
2024	11.7	12.7	13.2	13.8
2219	11.7	12.5	13.1	13.6
2618	11.5	12.4	12.9	13.4
4032	10.1	10.8	11.3	11.7
5083	12.3	13.2	13.8	14.3
6061	12.1	13.0	13.6	14.1
6151	12.0	12.9	13.5	14.0
7075	12.1	13.0	13.6	14.1

Figure 6

TYPICAL MECHANICAL PROPERTIES—ALUMINUM DIE FORGINGS[2,5]

Alloy and temper	Tensile strength, lb/sq in.	Yield strength, lb/sq in.	Elongation in 2 in. or 4D	Brinell hardness, 500 kg load 10mm ball	Shearing strength, lb/sq. in.	Endurance limit[3] lb/sq in.	Modulus elasticity[4] lb/sq in.
2014-T4	61,000	34,000	22	105	38,000	20,000	10.6×10^{-6}
2014-T6	70,000	60,000	13	140	42,000	18,000	10.6×10^{-6}
2014-T61	68,000	56,000	12	130	41,000	18,000	10.6×10^{-6}
2014-T652	70,000	60,000	13	140	42,000	18,000	10.6×10^{-6}
2024-T852	72,000	65,000	10	140	42,000	20,000	10.6×10^{-6}
2219-T6	64,000	45,000	14	115	37,000	15,000	10.6×10^{-6}
2618-T61	64,000	54,000	10	130	38,000	19,000	10.6×10^{-6}
4032-T6	55,000	46,000	9	120	38,000	16,000	11.4×10^{-6}
4032-T62	48,000	38,000	7	105	......	......	11.4×10^{-6}
4032-T72	44,000	34,000	8	95	......	......	11.4×10^{-6}
5083-H112	44,000	28,000	..	80	26,000	22,000	10.3×10^{-6}
6061-T6	47,000	43,000	17	100	31,000	14,000	10.0×10^{-6}
6061-T652	47,000	43,000	17	100	31,000	14,000	10.0×10^{-6}
6151-T6	48,000	43,000	17	100	32,000	11,000	10.2×10^{-6}
6151-T652	48,000	43,000	17	100	32,000	11,000	10.2×10^{-6}
7075-T6	80,000	70,000	14	150	46,000	23,000	10.4×10^{-6}
7075-T652	80,000	70,000	14	150	45,000	23,000	10.4×10^{-6}
7075-T73	73,000	63,000	13	140	44,000	22,000	10.4×10^{-6}
7075-T7352	73,000	63,000	13	140	44,000	22,000	10.4×10^{-6}

Figure 6 - Continued

CHEMICAL COMPOSITION LIMITS—ALUMINUM FORGING ALLOYS[6]

Alloy	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Others Each	Others Total	Al min.[7]
2014	0.50-1.2	0.7	3.9 -5.0	0.40-1.2	0.20-0.8	0.10	....	0.25	0.15	0.05	0.15	Remainder
2024	0.50	0.50	3.8 -4.9	0.30-0.9	1.2 -1.8	0.10	....	0.25	....	0.05	0.15	Remainder
2219	0.20	0.30	5.8 -6.8	0.20-0.40	0.02	....	....	0.10	0.02-0.10	0.05[8]	0.15	Remainder
2618	0.25	0.9-1.3	1.9 -2.7	....	1.3 -1.8	....	0.9 -1.2	....	0.04-0.10	0.05	0.15	Remainder
4032	11.0-13.5	1.0	0.50-1.3	....	0.8 -1.3	0.10	0.50-1.2	0.25	....	0.05	0.15	Remainder
5083	0.40	0.40	0.10	0.30-1.0	4.0 -4.9	0.05-0.25	....	0.25	0.15	0.05	0.15	Remainder
6061	0.40-0.8	0.7	0.15-0.40	0.15	0.8 -1.2	0.04-0.35	....	0.25	0.15	0.05	0.15	Remainder
6151	0.6 - 1.2	1.0	0.35	0.20	0.45-0.8	0.15-0.35	....	0.25	0.15	0.05	0.15	Remainder
7075	0.40	0.50	1.2 -2.0	0.30	2.1 -2.9	0.18-0.35	....	5.1-6.1	0.20	0.05	0.15	Remainder
7175	0.15	0.20	1.2 -2.0	0.10	2.1 -2.9	0.18-0.30	....	5.1-6.1	0.10	0.05	0.15	Remainder

1. To be multiplied by 10^{-6} (for example the coefficient of thermal expansion for alloy 2014 in column 2 is 12.5 x 10^{-6} which is 0.0000125 in./in./^{O}F).
2. Values obtained from standard half-inch diameter test specimens machined from separately forged coupons representative of the forgings.
3. Based on 500,000,000 cycles of completely reversed stress using the R. R. MOORE type of machine and specimen.
4. Average of tension and compression moduli. Compression modulus is about 2 percent greater than tension modulus.
5. Values listed are average and cannot be considered guaranteed minima for design purposes.
6. Composition in percent maximum unless shown as a range.
7. Aluminum percentage determined by difference.
8. Vanadium 0.05-0.15, zirconimum 0.10-0.25.

Figure 6 - Continued

WEIGHT ESTIMATES OF PROPOSED DESIGN CONCEPTS WITH COMPARISON TO EXISTING TRACKS

Part	CONCEPT 1 Single Pin	CONCEPT 2 Single Pin	CONCEPT 3 Double Pin	CONCEPT 4 Single Pin
Pin(s) and Nuts	3.3	4.8	9.6	3.3
Bushings	2.4	2.7	2.7	2.4
Pad	2.8	2.8	2.8	2.8
Body Rubber	1.0	1.0	1.0	1.0
Body	10.4	10.4	12.3	11.3
Centerguide	.9	.9	.9	.9
Drive Assembly	2.0	3.0	3.5	4.0
Total Weight Per Shoe	22.8	25.6	32.8	25.7
Weight per Foot of Track	45.6	51.2	65.6	51.4

Weight per foot of LVTP-7 Track (Per NAVSHIPS LVTP-7 Characteristic Data Sheet, May 1974)	62.8 Lbs.
Weight per foot of modified LVTP-7 Track for MICV (per U. S. Army Tank-Automotive Command Drawing 12250718, December 13, 1974	66.0 Lbs.

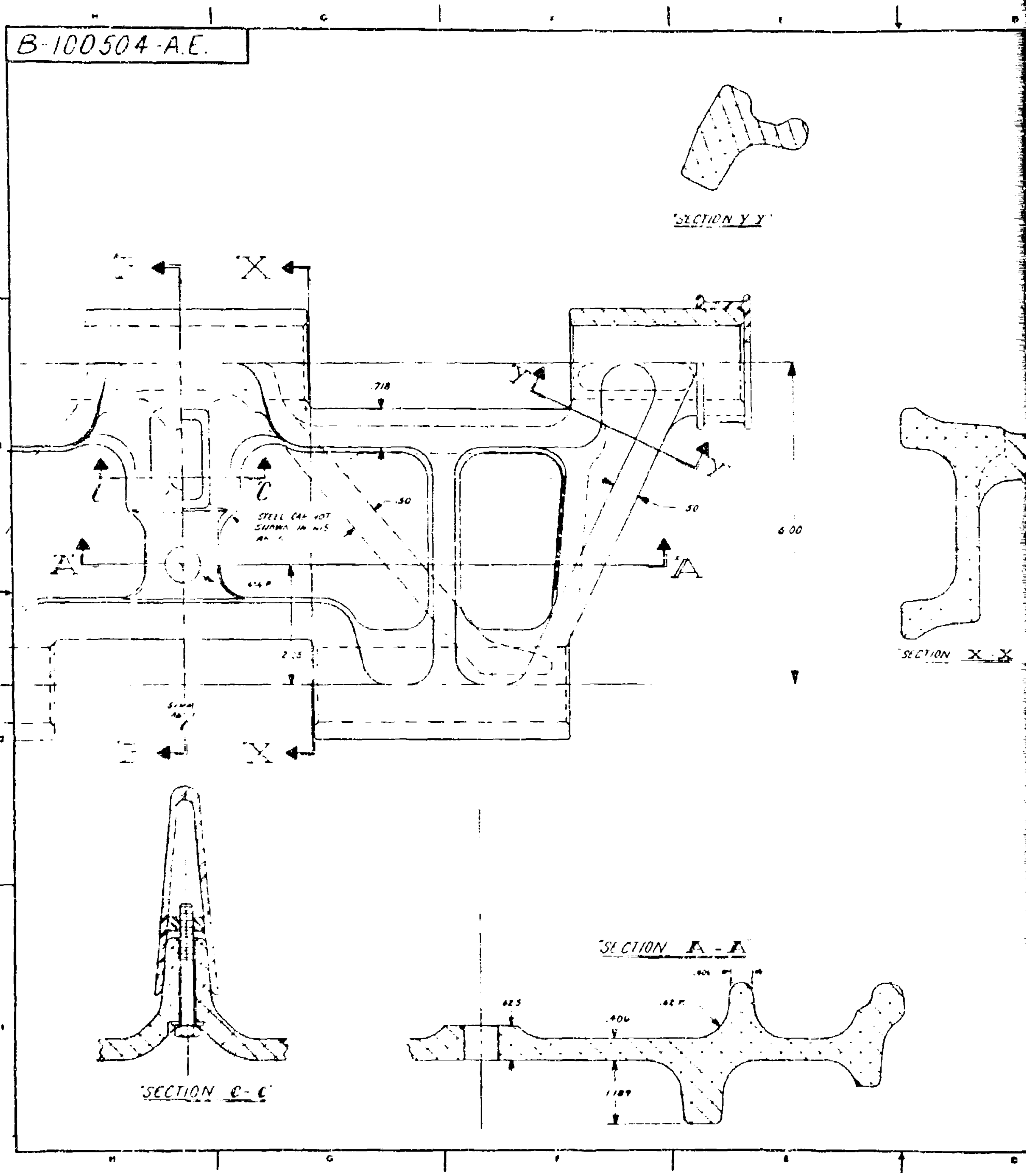
Figure 7

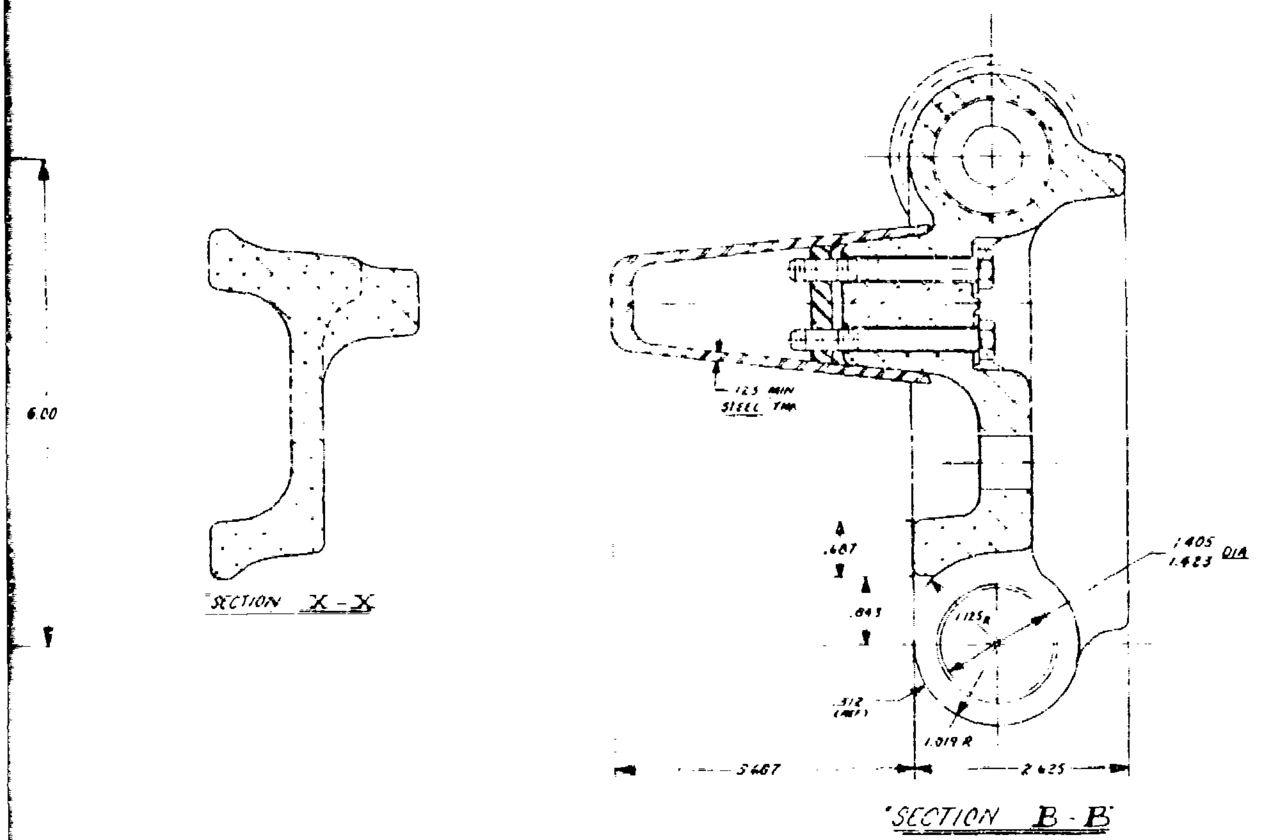
ESTIMATED PRODUCTION PRICE OF RECOMMENDED CONCEPTS

	Concept 2	Concept 4
Production Forging Dies	$22,250	$32,750
Production price (10,000 quantity) per pitch, assembled in sections, packaged for shipment	$ 78	$ 88

Figure 8

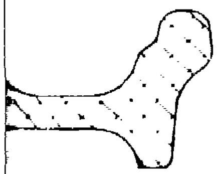
B-100504-A.E.


SECTION Y-Y
SECTION X-X
SECTION A-A
SECTION C-C
.718
.50
.50
6.00
2.25
.406
.625
1.189
STEEL CAP NOT SHOWN IN THIS VIEW
X
Y
A
C



DWG. NOT COMPLETE!

TYP DRAFT 5°



(REF BUREAU OF SHIPS DWG. 2584017)

ALCOA

PROPOSED LIGHTWEIGHT TRACK SHOE

CUSTOMER NAVAL SHIP R&D CENTER

MAT'L 2014-T61 | SCALE FULL | DATE SEPT. 30 1985

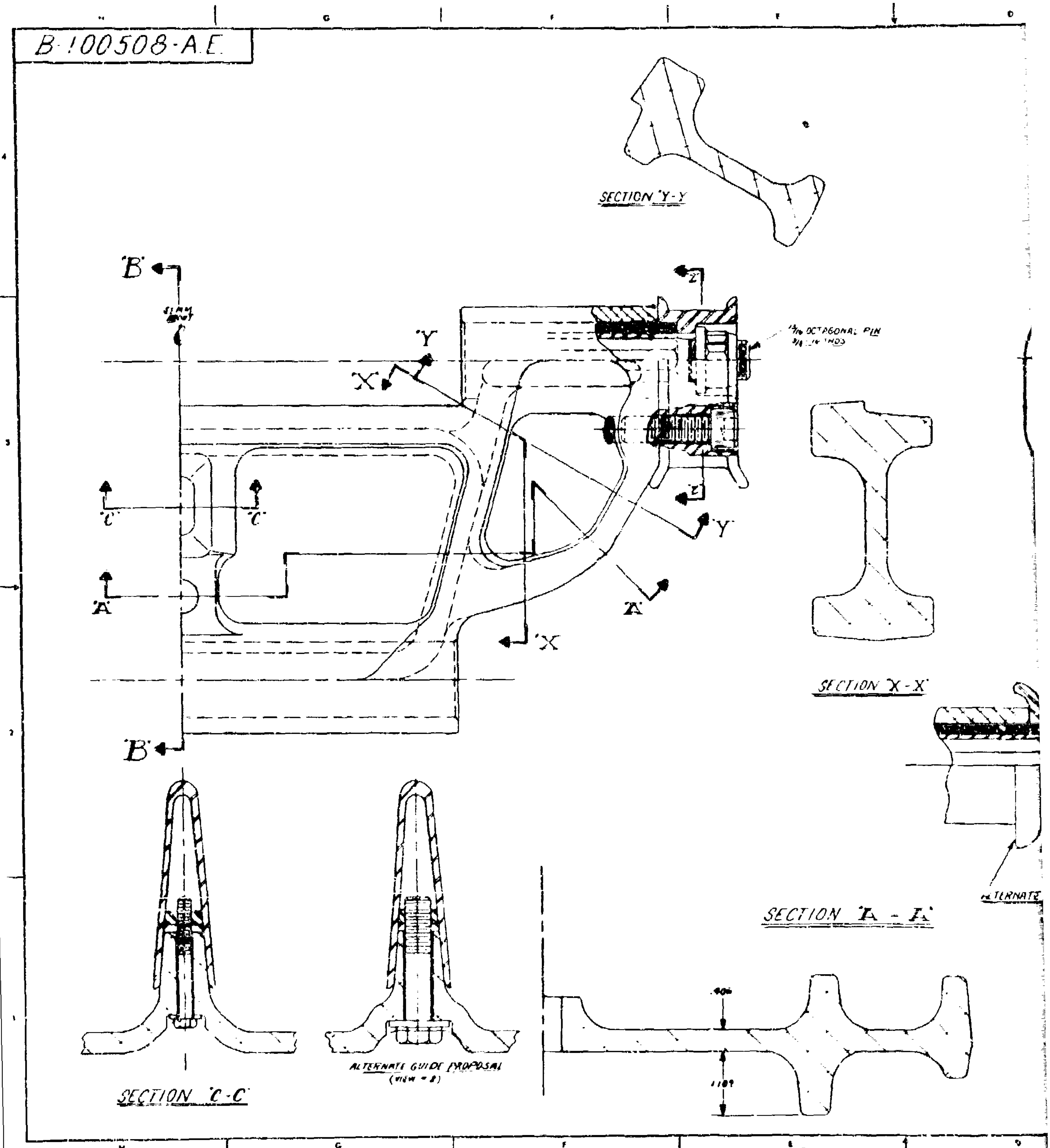
B-100504-A.E.

DRAWN BY L. C.

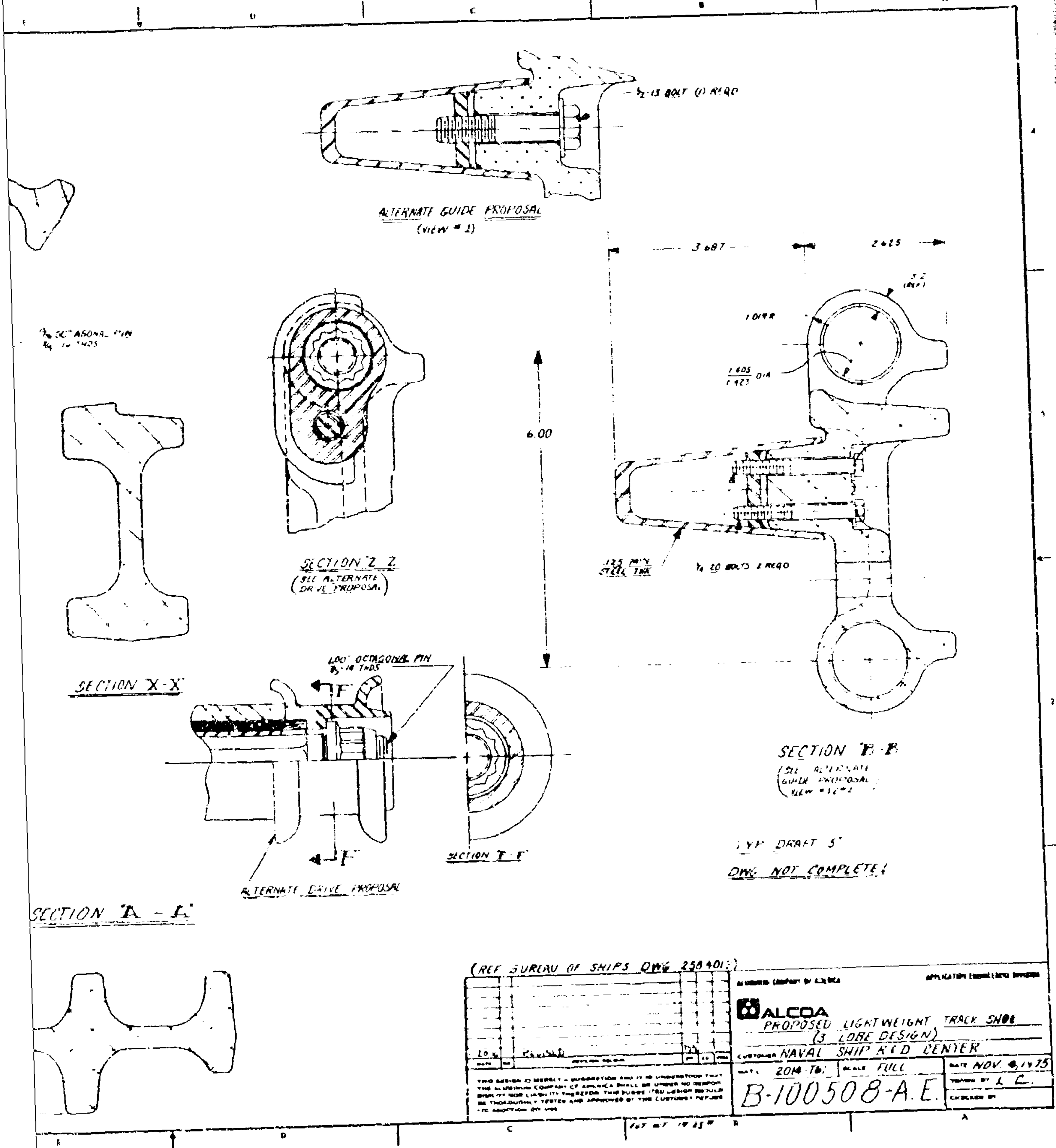
CHECKED BY

EST WT 13.25

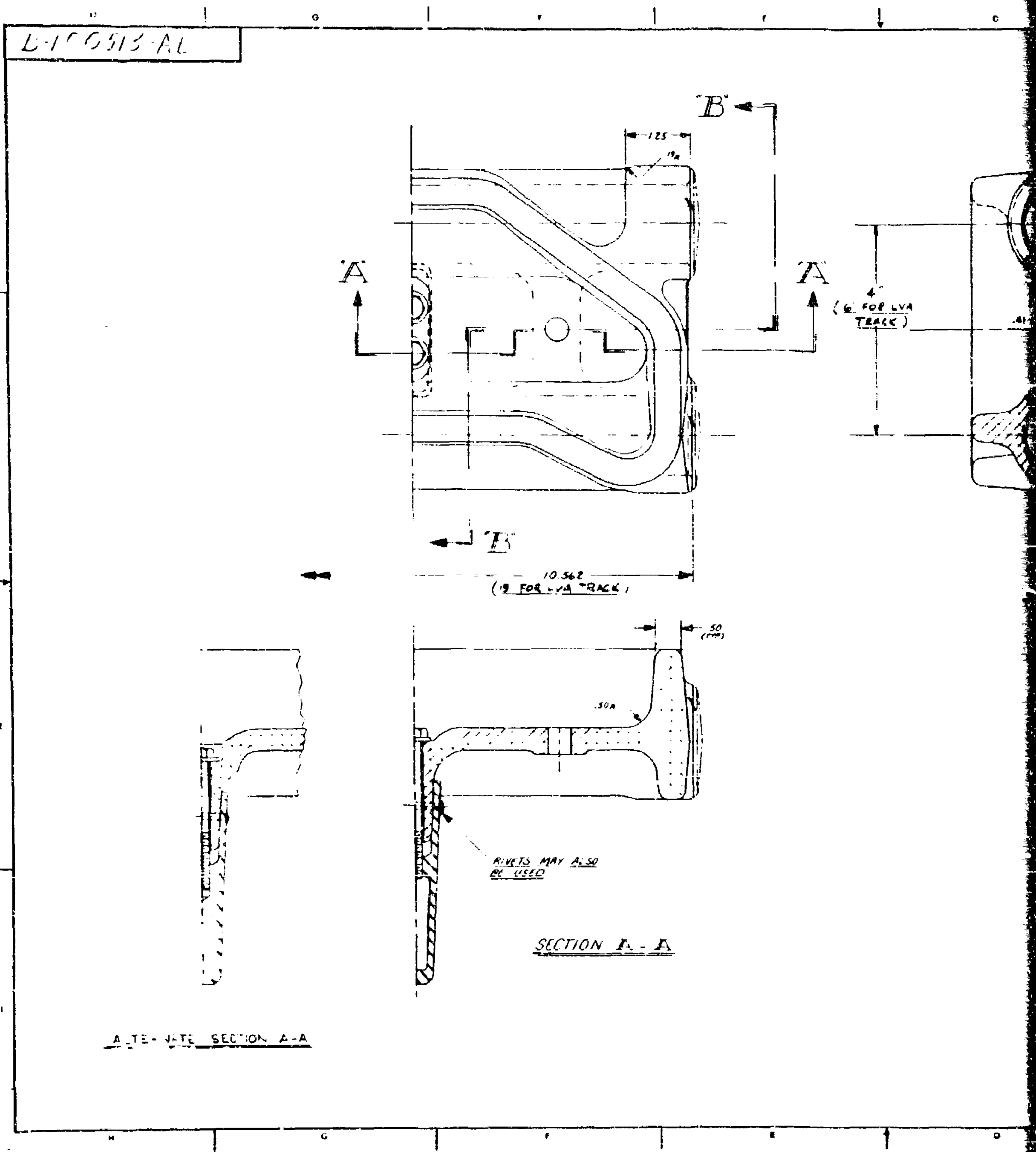
1.



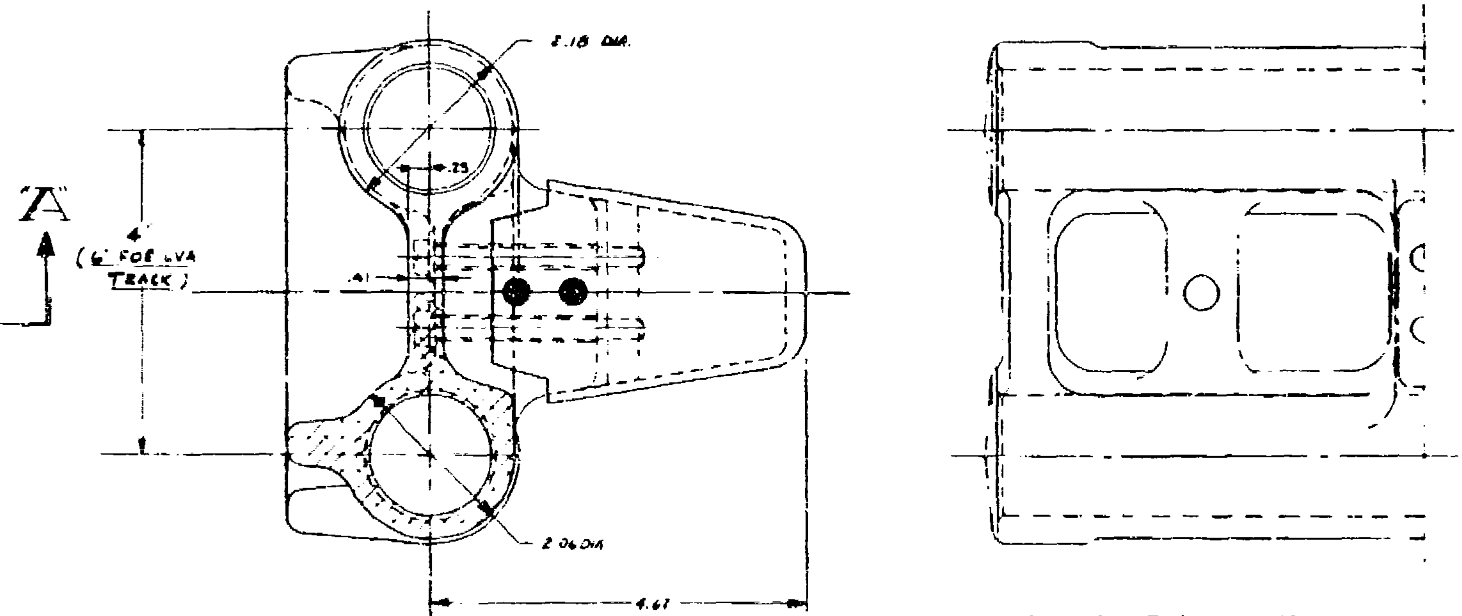
B-100508-A.E.
SECTION 'Y-Y'
SECTION 'X-X'
SECTION 'A-A'
SECTION 'C-C'
ALTERNATE GUIDE PROPOSAL
ALTERNATE
'B'
'Y'
'X'
'C'
'A'
'Z'
.406



½-13 BOLT (1) REQD
ALTERNATE GUIDE PROPOSAL
(VIEW # 1)
3.687
2.625
1.019 R
1.405
1.423 DIA
6.00
.125 MIN STEEL THK
¼ 20 BOLTS 2 REQD
SECTION Z-Z
(SEE ALTERNATE DRIVE PROPOSAL)
SECTION X-X
1.00" OCTAGONAL PIN
SECTION F-F
ALTERNATE DRIVE PROPOSAL
SECTION A-A
SECTION B-B
TYP DRAFT 5°
DWG NOT COMPLETE!
(REF BUREAU OF SHIPS DWG 2584012)
ALCOA
PROPOSED LIGHTWEIGHT TRACK SHOE
(3 LOBE DESIGN)
NAVAL SHIP R&D CENTER
2014-T6
FULL
NOV. 4, 1975
L. C.
B-100508-A.E.



B
A
.125
4"
(6" FOR LVA TRACK)
10.562
(9 FOR LVA TRACK)
.50 (TYP)
.50R
RIVETS MAY ALSO BE USED
SECTION A - A
ALTERNATE SECTION A-A



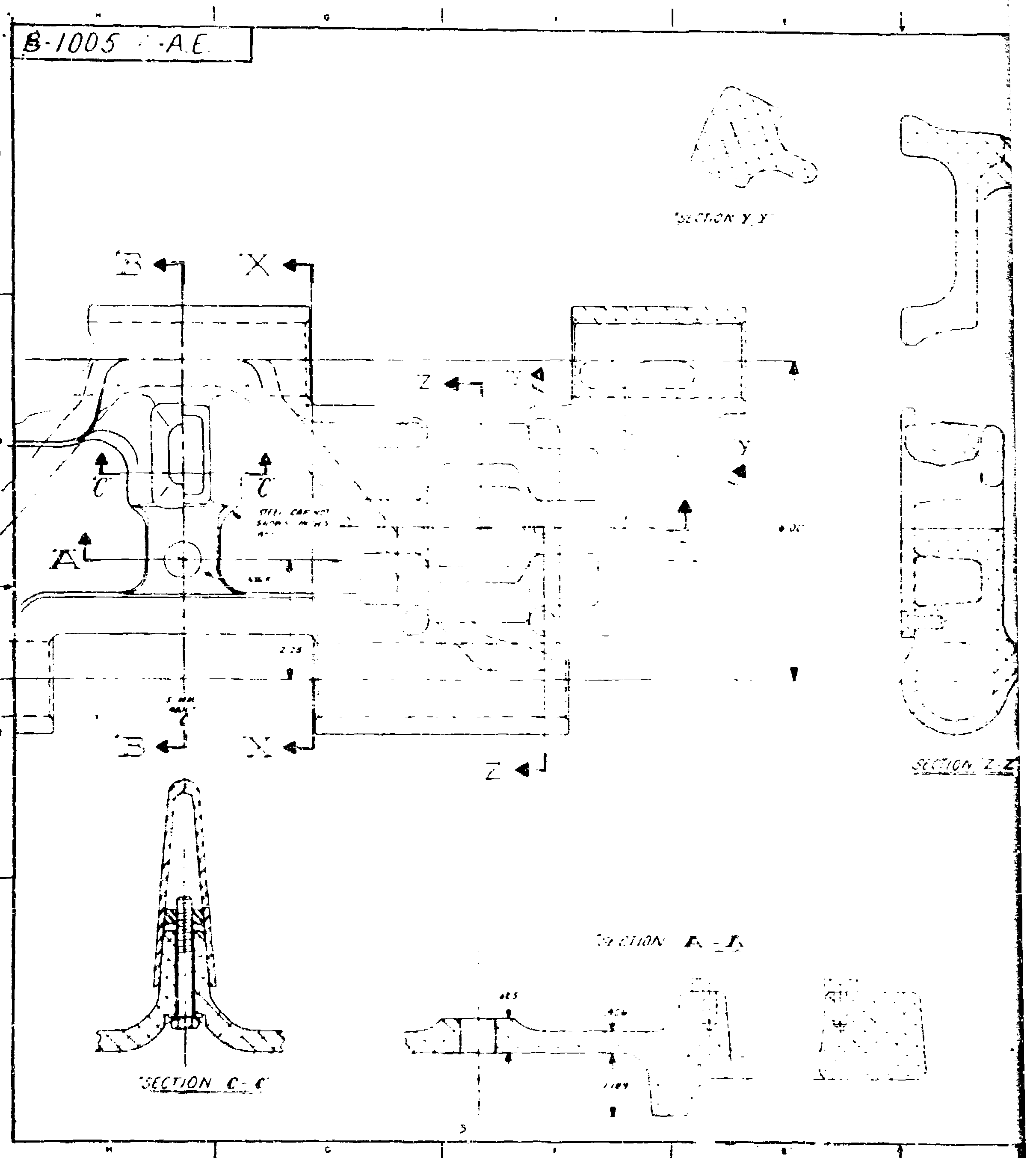
SECTION B-B

VIEW WITHOUT STEEL

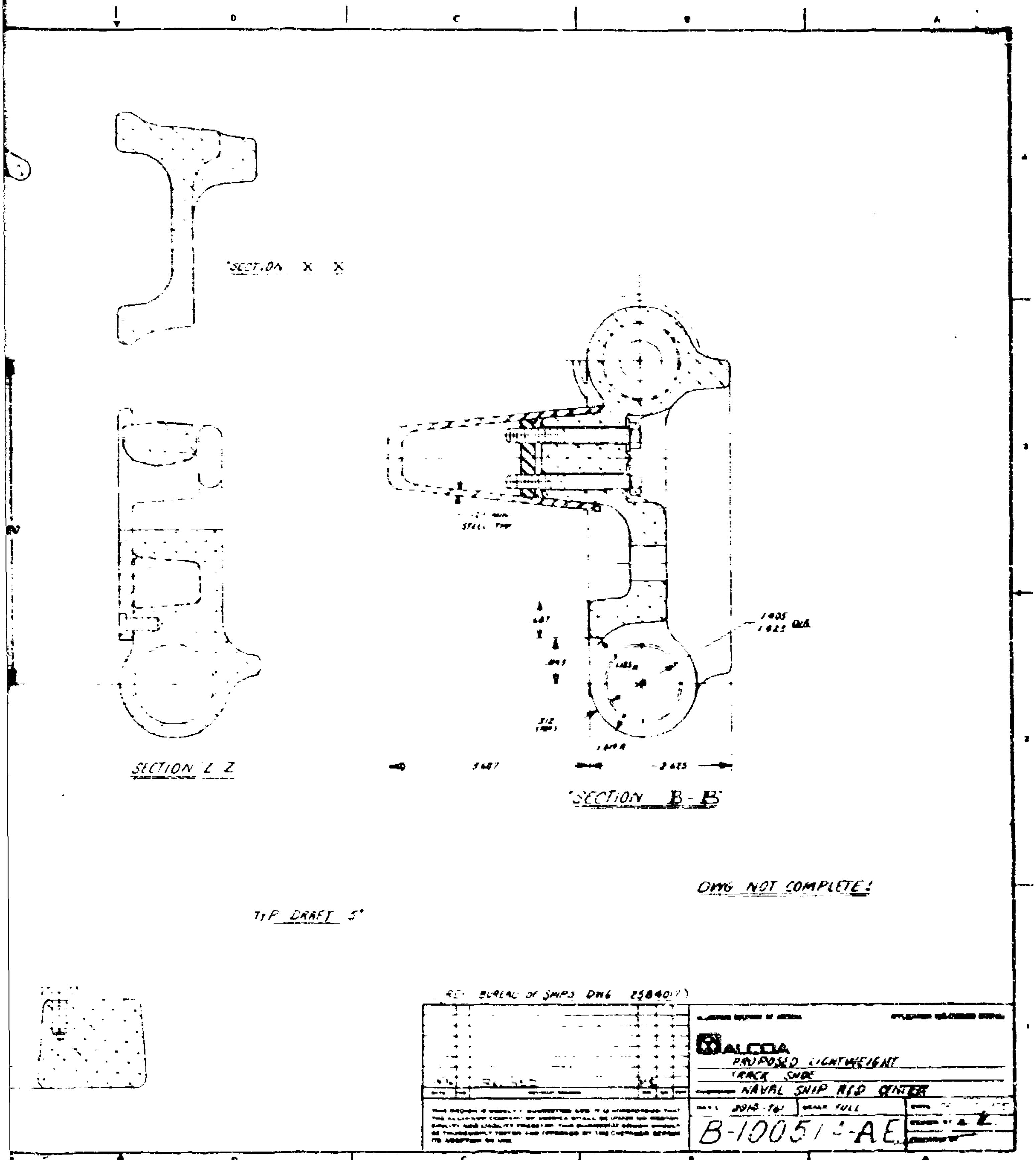
UNLESS SPECIFIED;
DRAFT ANGLES 5°
FILLET RADII .50 R.
CORNER RADII .19 R.

DWG. NOT COMPLETE!

ALCOA
FORGED TRACK SHOE PROPOSAL
DOUBLE PIN (WITH STEEL ... INSERT)
NAVAL SHIP R&D CENTER
2014-T61
SCALE FULL
DATE 12/8/75
B-100513-AE



B-1005 -A.E
SECTION Y-Y
SECTION Z-Z
SECTION C-C
SECTION A-A
B
X
Z
Y
C
A
2.25



SECTION X X
SECTION Z Z
STEEL TAP
1.405
1.425 DIA
.512
3.687
2.625
SECTION B - B
DWG NOT COMPLETE!
TYP DRAFT 5°
REF BUREAU OF SHIPS DWG 2584017
ALCOA
PROPOSED LIGHTWEIGHT
TRACK SHOE
NAVAL SHIP R&D CENTER
SCALE FULL
B-10051 -AE